KIGALI INDEPENDENT UNIVERSITY ULK

ECONOMIC ANALYSIS OF DETERMINANTS OF MAIZE POST-HARVEST LOSSES IN RWANDA.

CASE OF NYAGATARE DISTRICT (2021 - 2022)

By

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DECLARATION

I declare that this dissertation is wholly my original work, it has never been submitted before for any other degree award to any other University.

Signature ………………………………… **Date……./………………../2023**

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APPROVAL PAGE

This thesis titled "Economic Analysis of Determinants of Maize Post-Harvest Losses in Rwanda, case of Nyagatare District" has been done under my supervision and submitted for examination with my approval.

Signature ………………………………… **Date……./………………../2023**

Prof. Dr. RUFUS Jeyakumar

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LIST OF ACRONYMS AND ABBREVIATIONS

APHLIS:	African Postharvest Losses Information System
CIP:	Crop Intensification Program
EDPRS:	Economic Development for Poverty Reduction Strategy
FAO:	Food and Agriculture Organization
FGD:	Focus Group Discussions
GDP:	Gross Domestic Product
GoR:	Government of Rwanda
LGB:	Larger Grain Borer
MINAGRI:	Ministry of Agriculture and Animal Resources
MLR:	Multiple Linear Regressions
MT:	Metric Ton
NISR:	National Institute of Statistics of Rwanda
OLS:	Ordinary Least Square
PHHS:	Post-harvest Handling and Storage
PHL:	Post-harvest Loss
PHLs:	Post-Harvest Losses
SPSS:	Statistical Package for Social Science
SSA:	Sub-Saharan Africa
VIF:	Variance Inflation Factor
WFP:	World Food Program
ACF:	Action Contre la Faim
FSL:	Food Security and Livelihoods sector

OPERATIONAL DEFINITION OF KEY TERMS

Post-harvest losses:

Post-harvest Losses **(PHL**) is defined "as grain loss which occurs after separation from the site of growth or production to the point where the grain is prepared for consumption"(Rembold *et al.*, 2011) cited in (Gitonga *et al.*, 2013). Other authors, describe PHL as measurable quantitative, qualitative, and economics of grain loss across the supply chain or the post-harvest system, from the time of harvest till its consumption (J Aulakh & A Regmi, 2013; Tefera, 2012).

Post-harvest Handling:

In agriculture, postharvest handling (**PHH**) is the level of crop manufacturing without delay following harvest, including cooling, cleansing, sorting and packing. The immediate a crop is eliminated from the floor, or separated from its parent plant, it starts to deteriorate. Postharvest remedy largely determines very last great, whether or not a crop is bought for clean intake, or used as an component in a processed food product(Jideani *et al.*, 2017).

Agricultural crops losses:

Losses are a measurable reduction in foodstuffs and may affect either quantity or quality (Kumari & Pankaj, 2015). They arise from the fact that freshly harvested agricultural produce is a living thing that breathes and undergoes changes during postharvest handling. Loss should not be confused with damage, which is the visible sign of deterioration, for example, chewed grain and can only be partial. Damage restricts the use of a product, whereas loss makes its use impossible. Losses of quantity (weight or volume) and quality (altered physical condition or characteristics) can occur at any stage in the postharvest chain (Kumari & Pankaj, 2015).

Multiple Linear Regressions

Multiple Linear Regression is a statistical method used in data analysis and predictive modeling to examine the relationship between multiple independent variables (also called predictors or features) and a single dependent variable (also called the target or outcome variable) (James *et al.*, 2023). It is an extension of simple linear regression, which deals with only one independent variable and one dependent variable. In multiple linear regression, the goal is to find a linear equation that best describes the relationship between the dependent variable (Y) and the independent variables (X1, X2, X3, ..., Xn) (James *et al.*, 2023).

ABSTRACT

The economic analysis of determinants of maize post-harvest losses in Rwanda is a critical investigation that seeks to understand and assess the various factors influencing the extent of post-harvest losses in the maize sector of the Rwandan agricultural industry. This study aims to examine the drivers and root causes behind the losses incurred after maize harvest, shedding light on the intricate web of factors that impact this crucial aspect of food security and economic stability. Rwanda, like many other developing nations, faces significant challenges related to post-harvest losses in its maize production. These losses not only threaten the livelihoods of farmers but also have far-reaching implications on food availability and affordability for the broader population. To address this issue effectively, it is imperative to conduct an economic analysis that delves into the key determinants, cost implications, and potential solutions associated with maize post-harvest losses. This study will explore factors such as storage methods, transportation infrastructure, market access, pest management, and socio-economic factors that contribute to maize post-harvest losses. The main objective of the study was to conduct an economic analysis of the determinants of Post-Harvest Losses of Maize in Rwanda. It involved six maize-growing cooperatives across four sectors, with a sample of 207 respondents selected using a combination of probabilistic and purposive sampling techniques. Data was collected through structured questionnaires, interviews, focus group discussions, and desk reviews. The research adopted a quantitative approach, utilizing descriptive statistical techniques like percentages and frequencies, along with inferential statistics like multiple linear regressions to analyse the data. The primary findings of the study highlighted that the duration maize is stored before selling significantly impacts post-harvest economic losses for small-scale maize producers in Nyagatare District. Secondary factors included materials used in harvesting and transportation, the mode of transport, equipment for maize drying and shelling, and materials used in maize storage. Additionally, farmer knowledge played a crucial role, with results from multiple linear regressions showing that knowledge about maize quality parameters and transportation significantly affected post-harvest economic losses. The study therefore concluded that poor Post harvest losses is the only root cause that may undergo to economic failure for smallholder farmers in Nyagatare district of Rwanda. It is therefore recommended that there is a need of decentralized capacity-building efforts related to transportation equipment and mobile maize dryers to reduce moisture levels before storage.

Keywords*: Economic Analysis, Determinants, Post-harvest losses, Post-harvest handling, storage*

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background of the study

Today, one of the main global challenges is how to ensure food security for a world growing population whilst ensuring long-term sustainable development. According to the FAO, food production will need to grow by 70% to feed world population which will reach 9 billion by 2050. Further trends like increasing urban population, shift of lifestyle and diet patterns of the rising middle class in emerging economies along with climate change put considerable pressure strain on the planet's resources: declining freshwater resources and biodiversity, loss of fertile land, etc. Consequently, there is a need for an integrated and innovative approach to the global effort of ensuring sustainable food production and consumption(Akinnifesi *et al.*, 2010; Chartres & Noble, 2015).

In the meantime, while the number of food insecure population remains unacceptably high (F. FAO, 2012; W. FAO, 2012), each year and worldwide, massive quantities of food are lost due to spoilage and infestations on the journey to consumers (F. FAO, 2012). although the global food systems produce sufficient food to feed everyone, still in 2016 about 13.8% of food produced in the world get lost annually either through post-harvest mishandling, infestation by pests and diseases, or just mere waste at the table (Food and Agriculture Organization [FAO], 2019)**.** Over 30% of the food produced in SSA gets lost post-harvest along the food supply chain because of financial, managerial, and technical. In some African, Caribbean and Pacific ACP countries, where tropical weather and poorly developed infrastructure contribute to the problem, wastage can regularly be as high as 40-50% (Omoba & Onyekwere, 2016). Obviously, one of the major ways of strengthening food security is by reducing these losses. Along the renewed focus on investment in agriculture that began in 2008, there is an increasing interest in effective intervention for Post-Harvest Losses (PHL) reduction. The investment required to reduce PHL is relatively modest and the return on that investment rises rapidly as the price of the commodity increases. Action Contre la Faim (ACF) gives a particular attention to PHL reduction. During a research prioritization exercise undertaken by ACF Food Security and Livelihoods sector (FSL) in 2011, postharvest handling was recognized as one of the important areas requiring attention. It is of high importance in the effort to combat hunger, raise income and improve food security and livelihoods in the areas where ACF intervenes. In view of this, it was decided to develop a brief technical paper on postharvest losses and strategy to reduce them.

The rate of food production is reducing while hunger and malnutrition are on the increase (Boateng, 2016; Folayan, 2013). According to (Kiaya, 2014; Savary *et al.*, 2012), food production cannot satisfy the increasing food demand unless attention is focused on reducing post-harvest losses. This will create an opportunity for providing a substantial amount of food for consumption and other uses. Most of the postharvest losses are occurring in the developing countries while most of the increased food production is taking place in the developed countries (R. J. Hodges *et al.*, 2011; Kumolu-Johnson & Ndimele, 2011). In fact huge production loss has been the main causal component of farmers with limited and constrained resources in rural farm households in Sub-Sahara Africa (Cairns *et al.*, 2012). The term “postharvest loss” - PHL refers to measurable quantitative and qualitative food loss in the postharvest system (De Lucia & Assennato, 1994) cited in (Kumar & Kalita, 2017). This system comprises interconnected activities from the time of harvest through crop processing, marketing and food preparation, to the final decision by the consumer to eat or discard the food. Nowadays, interventions in PHL reduction are seen as an important component of the efforts of many agencies to reduce food insecurity. PHL is increasingly recognized as part of an integrated approach to realizing agriculture's full potential to meet the world's increasing food and energy needs. Therefore, reducing PHL along with making more effective uses of today's crops, improving productivity on existing farmland, and sustainably bringing additional acreage into production is critical to facing the challenge of feeding and increased world population. It is, however, evident for ACF that postharvest and value addition are integral components of strategies to improve agricultural productivity and linkages between farmers and markets which will help contribute to food security and economic development of its target population.

During the last decades, in Rwanda, agriculture had a lot of transformation. It contributed more than 30% of the GDP and employing over 70% of the population. Over the course of EDPRS I, agriculture contributed significantly to poverty reduction. In recognition to its potential in economic development, food security and poverty reduction, the government has set a very ambitious agriculture agenda aiming at an annual average growth of 8.5% over the course of EDPRS II (NISR, 2014). Agriculture is the main earner of foreign exchange in Rwanda, because of this important economic role, the agriculture sector holds a strategic position within the Government of Rwanda's (GOR) medium and long-term goals as outlined in the Vision 2020 and the Economic Development and Poverty Reduction Strategy (EDPRS) adopted by (Musabanganji *et al.,* 2016)**.** The Government of Rwanda through Crop Intensification Program (CIP) flagship which launched in September 2007 with the objective of increasing productivity in selected food crops while improving food security and self-sufficiency and focussing on Post-harvest handling mechanism. CIP has been investing heavily to increase hectares under consolidated production and productivity of staple food crops, including maize, rice, Irish potato, wheat, cassava, beans, soybeans, and peas. Production volumes have increased substantially over the past few years. For example, maize production has reportedly increased from approximately 100,000MT in 2007 to over 430,000MT in 2010, an increase of more than 400%. As adopted by (Musabanganji *et al.*, 2016). Furthermore, Maize production (metric tons) in Rwanda was reported at 525679 in 2011, according to the World Bank collection of development indicators, compiled from officially recognized sources. Table1.1 presents the evolution trends of maize for Rwanda that indicates total production quantity (tons)" for Rwanda which contains data from the year 1961 until 2017.

Competitiveness and market capacity for commercializing maize are still evolving, while other crops, including beans and Irish potatoes have strong markets and producers with stronger historical linkages to trade. Although there have been a sharp evolution of maize production in 2013, some years embarked with maize due to inappropriate Post-harvest technology including harvesting and threshing materials. To sort up with this issue, market strength in this value chain provides financial incentives for the value chain participants to focus on minimizing post-harvest losses and improve handling to increase the quantity and quality of product that reaches the market (Musabanganji *et al.*, 2016)**.**

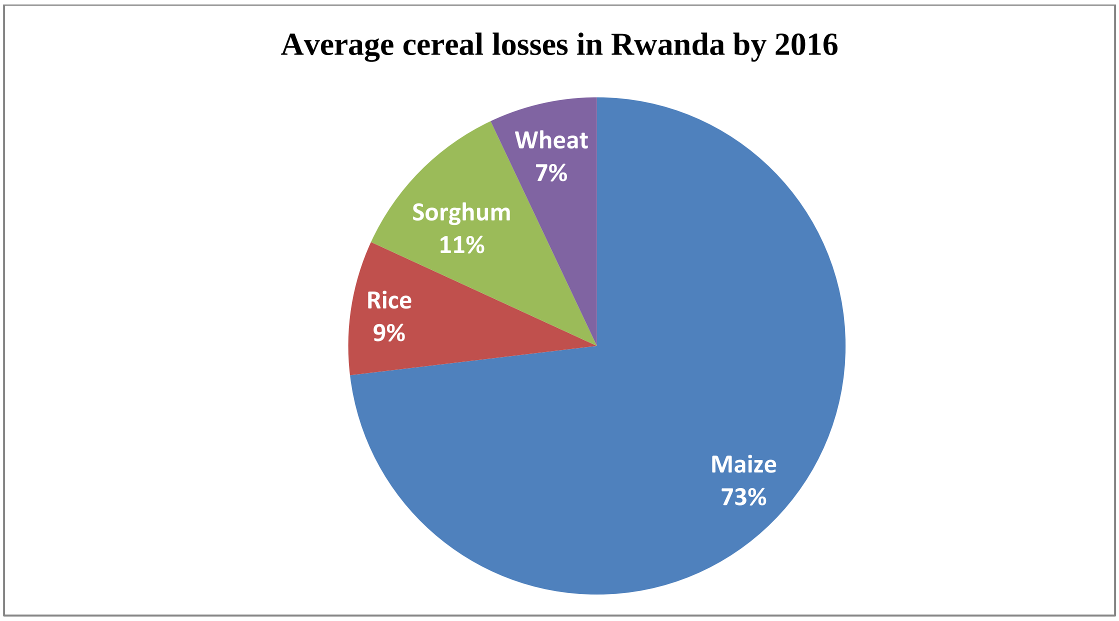

Figure1. 1: Average cereal losses in Rwanda

Source APHLIS, cited in (R. Hodges & Maritime, 2012)

1.1.1 Maize postharvest losses analysis

In Rwanda, since 2006 up to 2012, total maize production was about 1.97 million tonnes of which an estimated 20.2% (or 0.39 million tonnes) was lost during postproduction, thus over USD 114 Million were lost. Losses impact producers and consumers, reducing farmer incomes and raising consumer prices as a result of diminished supply as cited in (R. Hodges & Maritime, 2012). Furthermore they didn't demonstrates the real determinants of maize postharvest losses in the overall cereal postharvest losses, and the reasons behind maize postharvest losses as well, they are generally limited in analysing postharvest losses of cereals in general and thus present a research gap as adopted by (Musabanganji *et al.*, 2016)

Cereals constitute about 55% of the African food basket and for every 1% increase in food prices, food expenditure in developing countries decreases by 0.75%. In seeking to make improvements to cereal grain supply, an important element to consider is postharvest losses (PHLs) and major donors, including World Bank, African Development Bank, Rockefeller Foundation and Bill and Melinda Gates Foundation, are focusing on loss reduction (FAO, 2011) and (J Aulakh & A Regmi, 2013)**.** Postharvest operations for cereal grains follow a chain of activities , starting in farmers' fields and leading eventually to cereals being supplied to consumers in a form they prefer (Goletti & Samman, 2012). When determining the losses that may occur in this chain it is conventional to include harvesting, drying in the field and/or on platforms, threshing and winnowing, transport to store, farm storage, losses incurred in transport to market and market storage. In order to increase food security it is not enough to increase the productivity in agriculture but there is also a great need to lower the losses (Parfitt *et al.*, 2010) cited in (Lin *et al.*, 2013).

Interest in the reduction of PHL is not new. After the mid-1970s food crisis, considerable development investment went into PHL reduction for staple crops. In fact, in 1975, the United Nations brought postharvest storage losses into international focus when it declared that (FAO., 2010) “further reduction of postharvest food losses in developing countries should be undertaken as a matter of priority (FAO., 2010; Information *et al.*, 2012). The main aim of every subsistence farmer who engages in farming activities in each farming season is to be food sufficient throughout the whole year. In several countries, including Rwanda, this goal is sometimes not achieved because of high postharvest losses. It is very important for such countries to implement or introduce policies and technologies geared towards achieving food sufficiency (Hendrix & Brinkman, 2013).

In the developing countries most of the losses occur due to inefficient postharvest handling and storage facilities, which cause food to spoil or deteriorate before it reaches the market or final consumer (FAO *et al.*, 2011). Due to these losses that occur in developing countries, there is the need and potential to improved food security by reducing postharvest losses. Many staples stakeholders, both public and private, view maize as the priority staple crop for investment and intervention. It is a relatively new crop, having seen significant expansion in production over the very recent past as a result of substantial productivity and promotion investments by MINAGRI. The competitiveness and market capacity for commercializing maize are still evolving, while other crops, including beans and Irish potatoes have strong markets and producers with stronger historical linkages to trade. The market strength in these other staples provides financial incentives for the value chain participants to focus on minimizing post-harvest losses and improve handling to increase the quantity and quality of product that reaches the market (Musabanganji *et al.*, 2016)**.**

There is a perception across the staple crop value chains that post-harvest losses are significant, but there is little available data. An on-going effort from the GOR and its partners is necessary to quantify this issue at all levels of the value chain. Currently with maize, the limited size of the formal market demanding quality (and present constraints in production competitiveness) does not automatically equate to farmers being compensated for the investment required to minimize losses and improve quality through primary processing and handling**.**

Drying is most critical, both technically and economically, for cereals and legumes crops. Achieving a proper moisture level can stabilize the grain for further handling and storage, and can improve the milling quality. Field drying is the most economical, allowing the crop to naturally reduce moisture content upon maturation and prior to harvest. Rwanda is limited in this regard due to harvests during the rainy season. Use of the sun and air remain the most economical, particularly for very high moisture grain, which make technologies such as drying sheds and concrete drying grounds a natural next choice for producer and first aggregator level investment, although the grain remains exposed to pests, weather, and thieves. Since margins for the producers (and everyone along the value chain) remain thin, the economics of technological solutions for staples in relation to market price response must be calculated. In the rice sector there is installed mechanical drying capacity. Producers are found to prefer to expose their crop to some risk of loss in order to dry themselves, rather than take the price differential paid to compensate for the processor drying mechanically (Musabanganji *et al.*, 2016).

1.2 Problem Statement

Different authors argue that cereal losses occur within the whole supply chain due to limited resources such as post-harvest technology, knowledge and infrastructure (Parfitt *et al.*, 2010). Significant volumes of grain in developing countries (including Rwanda) are lost after harvest, aggravating hunger and resulting in expensive inputs such as fertilizer, irrigation water, and human labour being wasted. During postharvest operations, there may be losses of both cereal quantity and quality. Qualitative PHL can lead to a loss in market opportunity and nutritional value; under certain conditions, these may pose a serious health hazard if linked to consumption of aflatoxin-contaminated grain. Overall, food losses contribute to high food prices by removing part of the food supply from the market. They also have an impact on environmental and climate change, as land, water, and non-renewable resources such as fertilizer and energy are used to produce, process, handle, and transport food that no one consumes (Information *et al.*, 2012). In Rwanda, since 2006 up to 2012, total maize production was about 1.97 million tonnes of which an estimated 20.2% (or 0.39 million tonnes) was lost during postproduction, thus over USD 114 Million were lost. Losses impact producers and consumers, reducing farmer incomes and raising consumer prices as a result of diminished supply (Musabanganji *et al.*, 2016).

Furthermore they didn't demonstrates the real determinants of maize postharvest losses in the overall cereal postharvest losses, and the reasons behind maize postharvest losses as well, they are generally limited in analysing postharvest losses of cereals in general and thus present a research gap. In order to increase food security it is not enough to increase the productivity in agriculture but there is also a great need to lower the losses (Parfitt *et al.*, 2010). The study therefore seeks to analyse determinants of Post-Harvest Losses of maize in Nyagatare District, Rwanda.

1.3 Research Objectives

1.3.1 General objective of the research

The general objective of the study was to analyse the determinants of Post-Harvest Losses of Maize in Rwanda.

1.3.2 Specific Objectives

1. To estimate the magnitude and distribution of maize post-harvest losses in Rwanda
2. To estimate the economic impact of maize post-harvest losses on individual farmers
3. To recommend policy and intervention strategies for reducing maize post-harvest losses in Rwanda with a focus on cost-effectiveness measures.

1.4. Research Questions

1. What is the overall magnitude and distribution of maize post-harvest losses in Rwanda?
2. How do maize post-harvest losses impact the economic well-being of individual farmers in Rwanda, and what is the extent of this impact?
3. What policy and intervention strategies can be recommended for reducing maize post-harvest losses in Rwanda, considering the specific agricultural context of the region?

1.5. Significance of the study

Agriculture is expected to make a significant contribution to net foreign exchange earnings to Rwandan economic growth. Producers have uneven access to formal structured markets and marketing services. Maize is seen as a priority crop for investment and intervention in part because producers do not have many marketing options (Musabanganji *et al.*, 2016). As a result, this study sets to reveal the major determinants of postharvest losses of maize as a great contributor to agricultural produce of the country. It becomes important to carry out a research on this area of study to academically suggest ways of combating the perceived problems of the peasant scales farmers; also, it sets out to help proffer solutions to the problems being faced by the agricultural sector. With this information, local maize industry and national policy makers will have current information that identifies the major factors that drive postharvest losses of maize, and knowledge of which variables could be adjusted to ensure good and accurate maize postharvest technologies. This study will serve as a good background for those intending to carry out further research work on related topics.

1.6. Scope of the study

Scope in domain

The Government of Rwanda through Ministry of Agriculture and Animal Husbandry (MINAGRI) has a National Agricultural Policy that promotes agriculture in general. The policy encourages all categories of agricultural cooperatives, However Due to the diversity of agricultural cooperatives this study focused only on maize cooperatives involved in maize farming.

Geographical scope

The District of Nyagatare is one of the seven districts making the Eastern Province, and the district was selected because it has revealed among the districts with highest maize post-harvest losses. Objectives of this research will be achieved by analysing the determinants of postharvest losses of maize among cooperative members in Nyagatare district eastern province and the study will be carried out in 4 sectors that the researcher randomly selected.

Scope in time

The literatures reviewed cover a specific timeframe of the past ten years, where Data collection for this research span over a period of past 12 months, depending on the availability of resources and the need for comprehensive data. The research considered historical data and trends related to maize production and post-harvest losses in Nyagatare District of past ten years, but specifically two main agricultural seasons (2022A and 2021A Seasons) were referred to, season A starts in September and ends in Feb of the following calendar year.

1.7. Limitations of the study

This study was constrained by literacy level for cooperative members, data inaccessibility, low budget, time frame and other unanticipated occurrences. However the pilot study was carried out by the researcher to minimize the effects associated with the above mentioned challenges and the questionnaire was translated into Kinyarwanda because many respondents were not familiar with English.

1.8. Ethical Considerations

Ethical considerations were paramount in this research as it involves perceptions of maize farmers, here are some key ethical considerations that were observed during the research: **Informed Consent**: Before any activity of the data collection, research participants were fully informed about the research, its purpose, and benefits before agreeing to participate. **Privacy and Confidentiality**: Before the research starts, respect of participants' privacy was ensured by mentioning that any collected data remains confidential and is only used for the purpose of the research. **Anonymity**: Participants' identities were kept anonymous, to protect them from potential negative consequences that could arise from their participation. **Non-Discrimination and Fair Treatment**: All participants were treated fairly, equally and without discrimination. **Respect for Cultural Sensitivities**: Awareness of cultural norms, practices, and sensitivities of the participants was emphasized during the research.

1.9 Structure of the study

Apart from the preliminary parts such as declaration, acknowledge and abstract, this study is structured in five chapters as follows:

- **Chapter 1** talks about General Introduction of the study where the background, objectives, hypotheses, significance, scope, limitation of the study are described.
- **Chapter 2** highlights the Literature review. This chapter describes theoretical and empirical reviews, and the conceptual framework.
- **Chapter 3** talks about the research methodology that the study adopted, where the research design, study area, study population, sampling techniques, sample size determination, data collection processes, data analysis and model specification were described.

- **Chapter 4** discusses the results of the study, where both statistical and econometric analysis are described. And finally,
- **Chapter 5** provides the summary of the findings, conclusion and recommendations.

CHAPTER 2: LITTERATURE REVIEW

Introduction

This chapter was a survey of literature regarding to determine some of the factors that are responsible for postharvest losses of maize. The chapter began with a theoretical review to provide an economic theory which has to be tested by the use of the model. The chapter contains also the empirical literature on the maize postharvest losses, where figures are provided to show the status maize postharvest losses world widely up to Rwandan level. The chapter also considered the conceptual framework and critique of literature, research gaps and summary.

2.1. Theoretical Review

2.1.1. Economics of Postharvest Losses

Economic loss of cereal is the reduction in monetary value of the product due to a reduction in quality and or/ quantity of food (J Aulakh & A Regmi, 2013; Tefera, 2012). Postharvest operations for cereal grains follow a chain of activities starting in farmers' fields and leading eventually to cereals being supplied to consumers in a form they prefer. Losses occur in all post-harvest activities such as handling, storage, processing, packaging, transportation and marketing. Handling and processing of the food are of high importance in order to ensure food-safety reduce losses (Kitinoja *et al.*, 2011). When determining the losses that may occur in this chain it is conventional to include harvesting, drying in the field and/or on platforms, threshing and winnowing, transport to store, farm storage, losses incurred in transport to market and market storage. Losses are normally expressed as loss in dry weight of the cereal crop but losses of grain quality may be of equal or even of greater significance.

Soaring food prices in 2006/08 and the risk of food shortages in the future have renewed interest in agricultural development in Sub-Saharan Africa (SSA). For the majority of the population of SSA, cereal grains are the basis for food security and a vital component in the livelihoods of smallholder farmers. Cereals constitute about 55% of the African food basket and for every 1% increase in food prices, food expenditure in developing countries decreases by 0.75% (FAO., 2013)

In seeking to make improvements to cereal grain supply, an important element to consider is postharvest losses (PHLs) and major donors, including World Bank, African Development Bank, Rockefeller Foundation and Bill and Melinda Gates Foundation, are focusing on loss reduction.

Grain postharvest losses may be both the physical losses (weight and quality) suffered during postharvest handling operations and also the loss of opportunity as a result of producers being unable to access markets or only lower value markets due to, for example, sub-standard quality grain or inadequate market information. Wide ranging reviews of grain postharvest losses have been published by (R. Hodges & Maritime, 2012) and (Stathers *et al.*, 2013).

The harvesting process is the final stage in the production of crop. Proper handling of the crop after maturity and correct harvesting procedures may often be the difference between profit and loss. When the crop is sufficiently matured, it is desirable to initiate harvesting and attempt to harvest a large percentage of the crop with as high quality as possible. The time to begin harvesting will vary considerably in the various production area of the Nation. The crop’s maturity and the number of days of favourable weather that can be expected will determine the time to begin harvesting (CHATTHA, 2015).

Losses on yield can be due to improper harvesting techniques or harvesting too early or too late. If harvesting is too early, the plant may not have reached full maturity resulting in shrinkage of the grains. If harvest is too late, plant can lodge or stalk can break, grains can shatter or ears can drop and quality will deteriorate. Producers who are willing to take the time needed to adjust and operate their harvesting properly will reap extra profit from extra yield. Harvest losses from properly adjusted and operated harvesting should not exceed 3 percent as anything greater represents needless loss (CHATTHA, 2015). After harvesting, it is necessary to store the produce and protect it properly until it is processed into a usable product for consumers. Producer will often market their produce shortly after harvesting and move the product on into the channel of commerce. But in many cases, the producer will process and store a product for a period of time before it is used (CHATTHA, 2015).

The postharvest (post-production) and marketing system is a chain of interconnected activities from the time of harvest to the delivery of the food to the consumer, often referred to as “farm to fork”. Within this farm-to-fork continuum, a set of functions are performed. In grain value chains, examples of functions include: harvesting, assembling, drying, threshing/shelling, milling, storage, packaging, transportation, and marketing. However, the efficiency by which those functions are performed depends on the specific context including not only economic, social (e.g., cultural aspects, gender), technical, and business considerations, but also wider considerations related to the overall enabling environment, including availability of facilitating services and infrastructure, strong institutions, and macroeconomic aspects (Information *et al.*, 2012). The causes of the PHL are manifold and can occur at any stage between harvest and consumption, PHL can greatly be influenced by production conditions (pre-harvest stages). For example, end-of-season drought and mechanical damage to pods during pre-harvest are important factors contributing to aflatoxin contamination and subsequent mold growth during postharvest stages (Information *et al.*, 2012).

2.1.2 .Production theory: food losses and waste at the farm/firm level

Production activities entail the employment of limited resources - natural, human, financial and technical capital – in alternative uses to produce goods. Considering that an enterprise seeks to maximize its profit (total revenues - total costs), each rational enterprise will evaluate which goods produce by comparing the expected revenues and expected costs of different products feasible.

In agriculture labour, assisted by financial and technical capital, utilizes natural resources such as soil and water to transform inputs (e.g. seeds) in outputs (e.g. cereals). Some enterprises might be more efficient than others in combining together the factors of production (in some cases thanks to more modern plants). For these reasons, at a given market price, some companies realize a profit, while others suffer losses and, finally, some break-even, equal to the opportunity cost of capital employed (that is the tendency of perfectly competitive market) (Tudisca *et al.*, 2013).

2.1.3. Behavioural Economics, food losses and waste

Consumer demand is influenced by a number of cultural, psychological and social aspects that do not always follow criteria related to economic rationality and does not always fall under the concepts identified by neoclassical economics. This evolution lead to a 32 segmentation of the market that is functional to life style, consumption opportunities and working activities, cultural trends, globalization, migration, technological development, products standardization and other factors that are driving modern society. At the theoretical level the consequence of these trends is the development of alternative theories that consider consumers as rationale, but uncertain about some specific characteristics of the products (i.e. the taste in case of some food products) or try to introduce the contributions of other social sciences into economics. In order to explore the interconnections between different scientific disciplines an approach that combines the insights of psychology and economics to better understand and predict human decision is the behavioural economics theory (OECD, 2012) cited in (Hawkes *et al.*, 2013)**.**

According to literature factors driving to behavioural change can be classified in three areas: external factors (financial and efforts costs), internal factors (habits and cognitive processes) and social factors (societal norms and cultural attitudes) (Prendergast, 2007) cited in (Burbano, 2016). In addition behavioural economics brings in the theoretical debate also the fact that consumers do not always behave in their own best interests. All these elements (external, internal and social) are subject to extremely rapid transformations that lead to other changes in consumer behaviours and also in food industry decisions (Tudisca *et al.*, 2013)**..** For instance, fast changes might lead to rapid obsolescence of certain systems in the agro-food industry, leading to the formation of waste. This is also because the domestic demand is not always able to absorb the entire offer, either for quantitative reasons (supply > demand) or for the low purchasing power of local consumers. Therefore, there is the need to explore the linkages with the international market and to identify policies (employment policies, economic development policies, etc.) able to increase the consumer purchasing power and therefore the domestic demand. In industrialized countries, according to (Parfitt J., Barthel M., Macnaughton S., 2010), the development of a more efficient infrastructure system has led to a significant growth in the food processing sector. On one side, better infrastructures allowed farmers to "branch out into new foods, diversifying their incomes(Parfitt *et al.*, 2010) cited in (Galanakis, 2012).

2.2. Empirical review of existing literature

The Food and Agriculture Organization (FAO) of the United Nations and World Bank data revealed that PHL of cereal in SSA ranged between 5-40 %, worth around $4 billion (Zorya *et al.*, 2011).A recent report of a joint FAO/World Bank (Zorya S, Morgan N, Rios LD, 2011) shown that PHL of cereal in Eastern and Southern Africa account for over 40 % of the total PHL in SSA countries.

This represents losses of about $1.6 billion in value each year. Such losses are equivalent to the annual caloric requirement for at least 20 million people (FAO, Food losses and waste, 2013) or more than half of the value of total food aid received by SSA in a decade (Zorya S, Morgan N, Rios LD, 2011). Furthermore, it has been reported by (Meronuck, R. A., 1987) that post-harvest losses of maize in various storage facilities in undeveloped tropical countries ranged from 15-25 %. The PHL of maize can be described by leaky food-pipeline modified from (Abass *et al.*, 2014). As indicated in pipeline losses occur at all stages (field to market). However, higher losses occur at the field/harvest and storage. According to APHLIS, only 60-74 % of the harvested maize reaches the final consumer (Abass *et al.*, 2014). Figure 8 shows typical storage condition of maize during bumper harvest.

2.2.1Influence of storage duration of maize on its postharvest losses

A study by Munesue et al. (2015) further showed that the longer the storage time and the worse the storage conditions, the more severe the grain loss (Munesue *et al.*, 2015). Perishable commodities comprise of food products which last only for short periods of time such as a few days to weeks. For instance milk, meat, fish, fruits, tuber and vegetables etc. On the other hand non-perishables have longer shelf life lasting from months to years, for e.g. cereals, rice, lentils, and dried fruits. Different food groups vary in the way they are harvested from the field. For perishable food groups the process consists of plucking and storing in boxes or bags but in case of non-perishables such as cereals additional steps such as threshing and cleaning are required (Hodges, 2010) described a conceptual model that can be used to analyse post-harvest losses in grains at different levels of the supply chain flow.

2.2.2 Impacts of methods of postharvest handling and storage on postharvest losses of maize

During the sales process, grains are often stored temporarily by grain sellers before entering the market. As a result, storage conditions and methods affect the extent of grain loss and quality (Jaspreet Aulakh & Anita Regmi, 2013). Grains that are temporarily stored are susceptible to damage caused by rodents, insects, and microbes, which affects their quantity and quality. Therefore, good storage conditions could effectively reduce grain loss from insects or other pests (Mishra *et al.*, 2012). A study by Munesue et al. (2015) further showed that the longer the storage time and the worse the storage conditions, the more severe the grain loss (Munesue *et al.*, 2015). Therefore, grain sellers should improve storage conditions as much as possible. For example, reasonable control of storage temperature and humidity is important (Jaspreet Aulakh & Anita Regmi, 2013). Boxall (1986) also pointed out that it is necessary to maintain proper moisture content where grains are stored (Chen *et al.*, 2018). Good ventilation and dehumidification measures are needed as well. Additionally, insufficient storage conditions during display could increase grain loss. Our on-site survey also found that substantial differences existed in grain storage conditions among different sellers. For some grain sellers, their storage warehouses were well equipped with damp-proof floors, ventilators, and thermometers. For others, however, their storage warehouses were in dismal condition.

The reality is that many grain sellers often gather in a variety of markets, such as grain wholesale markets, farmers' markets, supermarkets, and so on. The size and scale of these markets differ, and the number of sellers varies. Grain wholesale markets, farmers' markets, and supermarkets are generally operated and managed by major investors or commissioned by third parties. In the market, a seller leases or buys the facilities (e.g., shops and warehouses) provided by the market management, and uses public facilities such as water, electricity, and roads to carry out sales and business activities. Therefore, the condition and management level of these facilities would affect the extent of grain loss during the sales process. Our on-site survey found that grain sellers often complained that neglect and mismanagement of the market contributed to grain loss during the sales process.

Premanandh (2011) pointed out that poor infrastructure in developing countries is a major contributor to grain loss, and these countries should increase their investment to improve key technologies and equipment (Premanandh, 2011). Koester (2014) argued that lagging infrastructure and facilities in developing countries is a major cause of higher levels of grain loss when compared to developed countries (Koester, 2014). Also, as transportation and storage represent important steps in the grain sales process, the level of mechanized equipment determines the production efficiency of grain sales and has a positive impact on reducing grain loss (Chen *et al.*, 2018). (Jiang *et al.*, 2018) pointed out that grain products are commodities with large sales volumes but low margins, and they require a lot of manpower and resources during the transportation, storage, and sales stages (Chen *et al.*, 2018). To maximize their interest, grain sellers often have a negative attitude toward equipment updates. In our survey, we also found that most grain sellers chose to reduce their investment in equipment to cut costs and increase profit due to intense competition pressure and low margins. Overall, wearing out of equipment is a common problem for grain sellers.

Losses on yield can be due to improper harvesting techniques or harvesting too early or too late. If harvesting is too early, the plant may not have reached full maturity resulting in shrinkage of the grains. If harvest is too late, plant can lodge or stalk can break, grains can shatter or ears can drop and quality will deteriorate. Producers who are willing to take the time needed to adjust and operate their harvesting properly will reap extra profit from extra yield. Harvest losses from properly adjusted and operated harvesting should not exceed 3 percent as anything greater represents needless loss (Bishop Lack P.C, Stephen R.C & William F.B, 2010) cited in (Kiburi, 2015). The study conducted by (FRUITS, 2016); World Food Logistic Organization (WFLO) (2010); (Kitinoja & Kader, 2015) who stated that the main factors responsible for higher levels of post-harvest losses include rough handling, use of poor quality packages, high postharvest handling temperatures and delays in marketing.

2.2.3 Impact of farmers' skills and knowledge on preventing maize postharvest losses of maize

According to (Kumar & Kalita, 2017) in their study in developing countries, lack of knowledge contributes to a significant amount of cereal loss during the post-harvest operations, despite being the region where people try to make the best of the food produced. However, in Mato Grosso Brazil, a study by (Martins *et al.*, 2014)on the managerial factors affecting post-harvest losses of cereals, showed that education level did not influence the magnitude of losses, although it was hypothesized that higher education level should lead to lower post-harvest cereal loss.

In Karnataka India, education was positively associated with good post-harvest cereal management, indicating that farmers who had some form of education experienced reduced post-harvest losses (Kumari & Pankaj, 2015). They reported that providing informal training, seminars, workshops and farming techniques to the farmers enabled them to be more receptive to the adoption of appropriate technology and, therefore, curbed the extent of post-harvest cereal loss. Similarly, in Pakistan, (Bashir *et al.*, 2012) demonstrate that education enables individuals to have access to information on best management practices, including on post-harvest losses and this enables them to curb losses and make better informed decisions.

The lack of awareness or poor knowledge of good post-harvest practices and technology by farmers has been identified as one of the challenges to be addressed if a meaningful Post-harvest losses of cereals reduction is to be achieved (Abass *et al.*, 2014; Affognon *et al.*, 2015; Kitinoja *et al.*, 2011). However, different studies have differing views on the influence of awareness and knowledge of better storage practices on post-harvest losses. According to (Kaminski & Christiaensen, 2014a)different factors plays a role. These include non-availability of the technologies individuals have knowledge or awareness of, lack of economic incentives to store and better protect food, non-cost effectiveness of technologies or the knowledge and other interventions being too narrow or short-lived to pay off. In different agro-ecological zones of Kenya including eastern region, training on grain storage and protection technologies did not necessarily result in lower post-harvest cereal storage losses as farmers who received training incurred similar magnitude of post-harvest losses as those farmers who did not receive the training (Ognakossan *et al.*, 2016). The study current study aimed at determining whether knowledge of improved storage system influenced post-harvest cereal loss in Wikililye location.

2.2.4 Influence of institutional factors on Post-Harvest economic Losses of Maize

Agricultural marketing extension is the provision of farmers with the know-how regarding activities from production to sale, to enable them to get their output to market most effectively (Nwafor *et al.*, 2019). In this regard, it includes activities related to rural credit, insurance, agricultural input, transportation, processing and storage of agricultural products, quality control, subsidies and collective activities of farmers such as cooperatives and farmers organizations. Agricultural marketing extension provides marketing intelligence, information on government policies, advice on post-harvest practices, strategies of product marketing and prices. Marketing extension redirects agricultural extension and advisory services from a limited focus on increasing production to improving farm management, market access and agribusiness. It also implies new roles for extension services that move beyond technology dissemination to the facilitation of innovation, knowledge brokerage and promoting dialogue among stakeholders.

Agricultural marketing extension services are knowledge services which assist small- to medium-scale farmers and other actors in agricultural value chains to increase their access to markets and secure benefits from commercialization (Narayanan, 1991) cited in (Ndoro, 2015). They are series of activities that assist farmers to gain better access to markets and reduce losses by making informed production decisions, prime of which is produced according to market requirements, including products, specifications, varieties, time of planting, and profitability of selected crops (Davis, 2008).

Marketing Extension services focus on the enhancement of knowledge, awareness and skills of different stakeholders of the sector on different aspects of marketing of agricultural produce. The farmer has to know what to produce as per the demand, where to sell, when to sell, whom to sell his produce et cetera (National Institute of Agricultural Extension Management: (Nwafor *et al.*, 2019). It is the total effort of advising and supporting farmers to produce profitable market-oriented commodities and adopt appropriate technologies and practices, collecting and communicating market-related information, identifying profitable markets and buyers, and linking of farmers to buyers, building marketing capacity of farmers, and facilitating organization of farmers to conduct collective marketing of their produce (Gebremedhin *et al.*, 2012); which the Agricultural Development Program (ADP) extension service make available to their clientele through the use of extension education process. In other words, agricultural marketing extension services are part of the overall services of the ADPs to their clientele.

According to (Yankson *et al.*, 2016), millions of smallholder farmers in developing countries such as Nigeria face incredible challenges marketing their farm produce. He identified a lack of market information, collusion among middlemen, and thus price determination, and lack of transportation facilities as the main challenges facing smallholders in many developing regions. Similarly, Food and (Godfray *et al.*, 2010) identified poorly developed marketing channels caused by poor transport facilities; few marketplaces with inadequate facilities, to facilitate and direct the movement of produce, and absence of grades and standards for the produce or standard weights and measures, little or no guidance on market information, and little commercial outlook to co-ordinate segments in the chain in respect to changes in volume, costs and prices. If Nigerian farmers have to withstand the possible onslaught of international competitors, both in domestic as well as overseas markets, marketing extension would be an effective instrument to safeguard farmers' interest through proper education and guidance on regular basis. The marketing extension services to assist small and marginal farmers in solving the problems faced in marketing their produce is, therefore a sine-quanon in the free trade environment.

The study conducted by (Lenis, 2012) stated that farmers' organization help them to participate in group activities as they tend to share ideas on profitable enterprises, adopt as well as engage in market activities of inputs acquisition or selling of produce thereby improving their profits through reduction of Post-harvest losses. Consequently, organized farmer groups are promoted as useful avenues for increasing farm productivity and implementation of food security and other development projects.

2.2.5 Estimation of maize PHL magnitudes and its distribution (PHL by stage)

Sub-Saharan Africa (SSA) remains highly dependent on agriculture in terms of its GDP share and employment (Chegere, 2018). It is estimated that crop production accounts for about 70 percent of typical incomes in this region, of which 37 percent is from grain crops (Chegere, 2018). However, 10–20 percent of the total grain produced in SSA suffers post-harvest physical losses (Chegere, 2018). This loss is valued at USD 4 billion annually, which is equivalent to the annual calorific requirement of 48 million people (at 2500 kcal per person per day). Food losses in developed countries are as high as in developing countries. However, in the latter, the largest proportion of food is lost during post-harvest handling processes and storage; while in the former the food losses occur mostly at retail and consumer levels (Chegere, 2018).

Investing in Post-harvest Losses (PHL) reduction, like any other investment, will be undertaken if the benefits outweigh the costs. To inform policy and facilitate optimal choices of mitigation approaches, a precise knowledge of the magnitudes of the losses, the drivers of the losses at each stage, and the net benefits of adopting mitigation practices is important (Gerber *et al.*, 2013). Empirical literature seems to concur that the total PHL in cereals in SSA are high[4] and concentrated in the handling and storage stages (Gerber *et al.*, 2013). However, studies analysing the factors driving PHL at different stages of the post-harvest system and economic assessment of recommended PHL mitigating practices are scarce (Kaminski & Christiaensen, 2014b). Moreover even these studies do not analyse the costs and benefits of adopting practices that are associated with lower PHL.

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2.2.6 Research gap

The study conducted by Chegere (2018) has found that concerns about food insecurity have grown in Sub-Saharan Africa due to rapidly growing population and food price volatility. Post-harvest Losses (PHL) reduction has been identified as a key component to complement efforts to address food security challenges and improve farm incomes, especially for the rural poor. Effective investment in PHL mitigation requires a clear knowledge of the magnitudes of the losses, the drivers of these losses at each stage, and the cost of mitigation. This study quantifies PHL experienced by maize farmers; analyses the role of post-harvest handling practices in PHL reduction; and conducts a cost-benefit analysis of adopting good PH handling practices. The study finds that maize farmers lose about 11.7 percent of their harvest in the post-harvest system. About two-thirds of this loss occurs during storage. The study also shows that good post-harvest handling practices are highly correlated with lower PHL. The cost-benefit analysis indicates that the adoption of most of the good practices is on average economically beneficial. The study discusses the puzzle of why some farmers still do not adopt them and points out some policy implications.

The research conducted by Shee *et al.* (2019) assessed the determinants of postharvest losses at each postharvest stage of maize and sweet potato (white fleshed and orange fleshed) value chains for smallholder farmers using our cross-sectional field survey data from two districts in Uganda. An ordered probit model estimation reveals that self-reported perceptions of the level of quantitative postharvest losses at different stages of commodity value chains are influenced by socio-economic factors as well as existing postharvest handling and storage practices. Increased years of education and training received on postharvest management are related to lower perceived levels of postharvest losses at key stages of value chains. Lower perceived postharvest losses are also associated with: at transport to homestead the use of sacks and bicycles as opposed to the use of baskets or transporting by trucks; at drying the use of tarpaulins as opposed to use of plastic sheets; shelling using bare-hands as opposed to beating cobs in sack with sticks; storage in a brick and mortar store as opposed to storing in living room in the house.

Due to poor performance of ordered probit model and cost benefits analysis approach, the current study employed the multiple linear regression and time series descriptive statistics to assess determinants associated to PHL of maize and then come up with clear picture of magnitude to which each determinant of maize Post harvest losses is affecting maize losses at different stages to close the knowledge gap.

2.3 Conceptual Framework

A conceptual framework is a structure or a set of ideas, principles, and concepts that provide a systematic and organized way to understand and analyse a particular topic or field of study. It serves as a theoretical foundation for researchers, scholars, and practitioners to develop and test hypotheses, conduct research, and interpret data. Conceptual frameworks are commonly used in various disciplines, including economics, sociology, psychology, education, and the natural sciences.

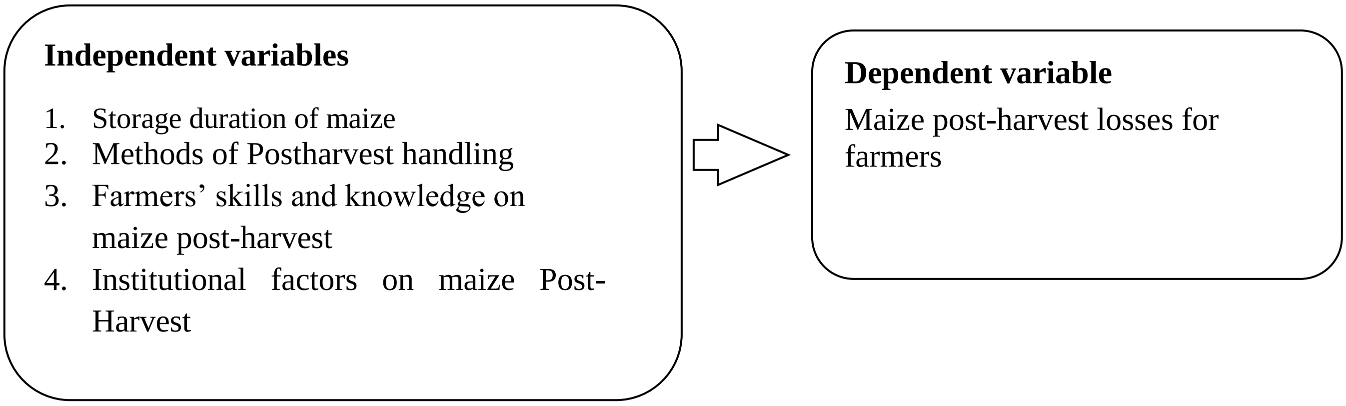

Figure2. 2: Schematic diagram of Conceptual Framework

Source: Elaborated by the researcher, 2023

CHAPTER 3: RESEARCH METHODOLOGY

Introduction

This chapter presents the way the research is based on a linear model that reflects the specific attributes of maize postharvest losses. The literature described in the background of the research serves as a building block to formulate and evaluate a maize postharvest losses-specific model. The purpose of this chapter is to describe the development of this model and to identify the regressions that have been performed for this analysis.

3.1. Research design

A research design is utilized to structure the research, to indicate that all the major elements of the research have been designed to work together. There are numerous types of research designs that one may decide to use (Meyers, 2013).This study will be a quantitative study and employed descriptive statistical techniques involving calculation of percentages, frequencies and inferential statistics such as multiple regressions. Descriptive design will be used in describing situations as they will be. Descriptive design will be used because it leads to proper profile development of the situation under investigation. Multiple regressions will be concerned with describing and evaluating the relationship between study variables variable and one or more other variables. More specifically, regression will explain movements in a variable by reference to movements in one or more other variables.

The study will use both primary and secondary data. Primary data will be gathered from farmers through face-to-face interviews using multi-stage and pre-tested questionnaires. A multi-stage questionnaire will be used to collect primary quantitative data in the selected households through a household survey. Secondary data will be obtained from the internet, published books and journals, and records of Ministry of Agriculture, Rwanda.

3.2. Study Area

The District of Nyagatare is one of the seven districts making the Eastern Province. The District of Nyagatare experiences small quantity of rains and hot temperatures. It is characterized by two main seasons: one long dry season that varies between 3 and 5 months with an annual overage temperature varying between 25.3°C and 27.7°C. The monthly distribution of the rains varies from one year to another. Agriculture and livestock are the main activities in the district where smallholder farming dominates the overall economy. Farming system is undermined by continuing land fragmentation as a result of land acquisition system (inheritance from father to son) and increasing population. The crops grown are principally food crops such as cassava, maize, sweet potato and sorghum.

3.3 Study Population

The target population is the total group of individuals from which the sample might be drawn (Meyers, 2013).The population included cooperative members, cooperative staff, local leaders and other control agencies such as Ministry of Agriculture and Animal Husbandry (MINAGRI) staff and NGOs that empowers agricultural cooperatives in Nyagatare District. The total target population will be 429 registered agricultural cooperative members from 6 agricultural cooperatives. The study were conducted in 4 sectors of Nyagatare District namely Rukomo, Mukama, Tabagwe and Mimulito analyse the determinants of postharvest losses of maize.

3.4. Sampling techniques

Sampling is the procedure of selecting a representative group from the population under study (Ritchie *et al.*, 2013). While conducting this study, probabilistic sampling technique and purposive sampling will be adopted. This is to imply that all the members of the population stand a chance of being selected (Holloway & Galvin, 2016; Mayring, 2014). A sub population of cooperative lead famers, committee members will be integrated in analysing the determinants of postharvest losses of maize in Nyagatare.

3.4.1 Sample size determination

The executive and controlling committees and lead farmers of cooperative were the targeted population to respond on questions and later, a sample size was calculated basing on sample frame of cooperatives in Nyagatare provided by the district cooperative officer. The sample size was calculated using Slovin formula:

$$n = \frac{N}{1+N(\alpha)^2} \qquad (1)$$

Where **N=**429 dairy farmers is the sample frame or total population, n is the sample size and α is the margin error. α: predicted confidence (for confidence interval of 95%, equal to5% significance level)

$$n = \frac{429}{1\pm 429(0.05)^2} = 207 \qquad (2)$$

The sample size was made up of 207 respondents from 6 agricultural cooperatives selected randomly from 4 sectors in Nyagatare District.

3.4.2 Sampling frame

Noting that the population under study was heterogeneous, a random stratified sampling design will be employed for the sample frame determination. This is because using such a design will help to capture all the representatives of each stratum and it constitutes the blueprint for the collection, measurement and analysis of data (Kothari, 2004). Sample frame was determined using random stratified sampling.

Table 3.1: Sampling frame

Number	Cooperative	Members	Sample
1	CAMARU	40	19
2	CODPCUM	69	33
3	KOABITADU	48	23
4	COOPAMA	165	80
5	CODAR	52	25
6	KOTEBARU	55	27
Total	**6**	**429**	**207**

Source: Elaborated by the researcher

3.5. Data collection instruments

3.5.1. Questionnaire

The analysis of the determinants of postharvest losses of maize applies quantitative methods under different characteristics of respondents. Therefore, a questionnaire will be administered to the main respondents considered as cooperative lead farmers, committee members and staff to analyse determinants of postharvest losses of maize. An assessment questionnaire is comprehensive with different components among them; type of storage facility, methods of postharvest handling and storage, storage duration, distance from storage to markets, skills and knowledge on maize postharvest techniques. Therefore this will be achieved through collecting information by interviewing or administering a questionnaire to a sample of individuals, which aims to collect information about member's opinions on determinants of maize postharvest losses.

3.5.2. Key Informants' Interviews

The main purpose of using key informants interview was to complement the main instrument (questionnaire). In total, 9In-depth Interviews (IDI) will be conducted from the following categories: Cooperative Focal Persons at District level, non-governmental Organization representatives, and agricultural cooperative focal persons at national level. The selection of key Informants at both Sector and District level will be based on the concentration of large number of cooperatives in the respective areas. For the other categories, the selection procedure will be carried out on a random basis approach according to their roles in collaboration with agricultural cooperatives at both national and local level.

Table 3.2: Categories of Key Informants Interviewed

Key Informants	Institution	Numbers
Cooperative Focal Person at District level	Nyagatare District Agronomist	1
Non-government Organization	RDO	2
Sector	Agronomists	4
Agricultural Cooperative Focal person at National level	RAB	1
Total		9

Source: Elaborated by the researcher, 2023

3.5.3 Focus Group Discussions (FGD)

Though the interviews, questionnaire and desk review were provided plenty of useful information, the Focus Group Discussions helped to get further information on determinants of postharvest losses of maize. Consequently the researcher randomly selected 3 cooperatives and attended their aggregation and sales meeting in order to observe and brain storm on maize postharvest losses.

3.5.4 Secondary data

This technique enabled the Researcher to gather and make use of various specialized reports, scientific work as well as activity reports specifically dealing with issues related or associated to cooperatives. In the same way, it helped to analyse legal, regulation texts and public policies related to the theme of the study. The role of the desk review equipped the researchers with a general overview of the topic of research, gained a deep understanding of the issues involved and complements other research instruments.

3.6 Pilot test

Conducting such a sensitive study helped the researcher to set measures that ensure quality data and information. A pilot survey was conducted to test the quality of research tools, mainly the questionnaire as well as their understanding by the respondents and promoted the use of a participatory approach in developing research instruments.

3.7 Data analysis and interpretation

The data from key informant interviews and FGD will be analysed to complement the findings from the questionnaire. The questionnaire data will be captured in SPSS, both descriptive and econometric analyses will be carried out on the data using STATA version 12 and SPSS Version 16 computer packages (for both t-test for quantitative).

3.8. Model Specification

Modelling it is the process of producing the correct functional form of a phenomenon and selecting which variable to include. Model specification was applied in this research in order to have reliability of results. The model used in this research is not behavioural but statistical (Gujarati, 2009) cited in (Bernard, 2017). Therefore, the determinants of postharvest losses of maize will be assessed using multiple regression analysis. The multiple regression models are indicated below to give an image that agricultural postharvest losses of maize depends on. The multiple regression model used in this research is expressed as follows:

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots \beta_i X_i + Ui.}$$

Where: Y: Dependent variable (Maize post-harvest losses), β1, ……… βi: Regression coefficients of the explanatory variables (parameters)

β0: Intercept which can be interpreted as the average value which Y would take if all of the explanatory variables took a value of zero. **X_1, …………X_4**: Vectors of explanatory variables (independent variables). **X_1**=Storage duration, **X_2** =Methods of postharvest handling and storage, **X_3** = Skills and knowledge on postharvest and storage ; **X_4** = institutional factors on Post-Harvest losses of Maize and **U_i**= Basket of remaining variables and errors related to usage of data (error term).

The model has been used partially used during the analysis of how each explanatory variable is affecting the independent variable.

CHAPTER 4: RESEARCH FINDINGS

4.0 Introduction

A research presentation for the analysis and interpretation of findings is a formal or semi-formal communication in which you present the results of a research study, often in an organized and visual format, to an audience. This presentation typically includes an in-depth discussion of the data, what the data means, and the significance of the findings in the context of research question or objectives. This chapter deals with the findings, descriptive statistics and econometric models with the aim of analysing the determinants of Post-Harvest Losses of Maize in Nyagatare District, Rwanda.

4.1. Descriptive statistics of socio-economic characteristics of maize growers

This section discusses the socio-economic characteristics of the sample households in the study area. These socio economic variables include sex, age, marital status, occupation, acreage and farming experience of maize growers in Nyagatare district as the case of interest.

4.1.1 Gender distribution vs age group of maize producers in Nyagatare district

Gender distribution vs age group of maize producers in Nyagatare district" is a research topic or study that involves examining the demographics and characteristics of individuals who produce maize in Nyagatare district, with a specific focus on their gender and age.

Table 4.1 : Gender distribution vs age group of maize producers

Age group	Female count	Male count	Female %	Male %	Age group %
Below 19	2	3	43	57	2.4
20 – 29	20	36	35	65	27.3
30 – 39	30	31	49	51	29.5
40 – 49	25	20	55	45	21.5
50 – 59	13	27	33	67	19.5
Total	**90**	**117**	**43**	**57**	**100**

Source: Primary Data collected and analysed by the researcher

Table 4.1 pertained to main socio economic characteristics of maize growers from Nyagatare district. The results show that the majority (29.5%) of maize farmers in Nyagatare fall under the age group of 30 – 39 and the minority of maize farmers are below 19 years old, where the age group with majority (55%) of female is 40 – 49 years old in contrast of the age group of 50 – 59 with few (33%) female farmers. Looking at male farmers, the results reveal that the majority of males farmers belongs to the age group of 50 – 59 years old, where the minority of males farmers are between 40 – 49 years old.

Results in table 4.1 indicates that 57% of the respondents were males while 43% of them were females. A higher proportion of males were observed across all cooperative of maize producers disagree with the National Seasonal Agriculture Survey (SAS) from NISR, 2016 adapted by (Ngaruye *et al.*, 2016) where the figures showed that in 2016 Season A, the distribution of agricultural operators in Rwanda by gender was 70 % male and 30% female.

In addition also, the findings coincided with the findings from NISR, 2016 where it revealed that the distribution of female agricultural operators in Rwanda was high in the age group of 55 and above (34.2%) followed by 23.5 percent of female agricultural operators in age group of between 45 and 54, 21.3 percent of female agricultural operators in age group of between 35and 44, 16.7 percent in age group of between 25 and 34 and 4.4 percent in age group of between 14 and 24 years respectively.

4.1.2 Marital status for maize producers

The marital status of maize producers refers to the relationship status or family structure of individuals or households involved in maize production. Understanding the marital status of maize producers can provide insights into their socio-economic conditions, support systems, and potential labor availability within the households.

Table 4.2: Marital status for maize producers

Marital status	Freq.	Percent
Single	43	20.77
Married	164	79.23
Total	**207**	**100**

Source: Primary Data collected and analysed by the researcher

The results from table 4.2 indicated the distribution of maize growers by marital status. The survey results indicated that 79% of the sampled farmers were married while 21% of the respondents were single status. The findings are different with report conducted by (NISR, 2014) cited by Jean Christophe Nsanzimana, in which stated that the proportion of married women increased from 29% in 2005 to 35.1 % during this period of 2005. The big percentage of married women appears between 30-34 years of age (62.4%). The report states that 34.1% of Rwandan men are in formal marriages, the same as it was in 2005.However, 13.4% of Rwandan men live together with their partners in informally unions and the high number of Rwandan men living in informal unions is observed between 25-29 years of age where it’s 22.2 % respectively.

4.1.3 Main occupation of respondents from maize producers

The main occupation of respondents who are maize producers typically refers to the primary source of income or employment for individuals or households engaged in maize cultivation. The main occupation of maize producers can vary depending on the region, socio-economic conditions, and the scale of maize production.

Table 4.3: Main occupation of respondents

Main occupation	Freq.	Percent
Farmer	190	91.79
Trader	17	8.21
Total	**207**	**100**

Source: Primary Data collected and analysed by the researcher

The findings from the field survey presented in table 4.3 summarize the distribution of respondents by occupation. The results showed that 92% are engaged in crop farming/ farming activities while 8% of the total sampled maize producers were traders in their respective zones.

The findings are in line with the current statistics from (NISR, 2014) cited in (Bizimana *et al.*, 2012).

4.1.4 Education background of maize producers in Nyagatare

The education background of maize producers in Nyagatare, Rwanda, can vary widely depending on individual circumstances and generational factors. However, here is a general overview of the likely educational backgrounds of maize producers in the district of Intervention.

Table 4.4: Education background of maize producers

Education levels	Freq.	Percent
None	64	30.86
Primary	100	48.15
Secondary	20	9.88
University	5	2.47
Vocational	18	8.64
Total	**207**	**100**

Source: Primary Data collected and analysed by the researcher

Table 4.4 showed that 30.86% of the respondents had no formal education (analphabet, unable to read and write) while 48.15% had attended primary school from primary one form of education or the other to primary six; secondary education accounted for 9.88 percent, University education accounts 2.47% only while 8.64percent attended tertiary education either vocational trainings and TVET respectively. This is in contradiction with the national statistics from Rwanda reported by NISR, 2016 adapted by (Mukama, 2018) in which the survey results of the 2016 SAS Season A illustrated that 66.6% of agricultural operators had attended primary level education, 25.9% had no education, 6.5% attended secondary level education and only 1.0% had attended tertiary level education. This implies that farmers in the area are relatively educated and hence likely to be receptive to new innovations, and will easily adopt them for greater productivity. These findings agree with the results of (Neiland *et al.*, 2016) who confirmed that farmers cultivating small farms are illiterate or uneducated.

4.1.5 Acreage ownership of maize producers in Nyagatare district

Table 4.5: Acreage ownership of maize producers

Acreage	Freq.	Percent
Over 10 hectares	10	4.83
Between 5-10 hectares	41	19.81
Between 1-4 hectares	76	36.71
Less than a hectare	80	38.65
Total	**207**	**100**

Source: Primary Data collected and analysed by the researcher

The results presented in table 4.5 indicated that about 38.7% of the total sampled respondents owned the acreage below 1ha of arable land, followed by farmers owned land ranging from 1-4ha of land representing 37% of the total sampled farmers in the preselected cooperatives. There are also maize growers owning the land ranging from 5-10ha representing 20% and finally maize producers considered as large scale farmers possessing acreage greater than 10 ha of arable land covering 5% of the sampled maize producers in Nyagatare district. The findings agree with the report of (Kathiresan, 2012) and (Bizoza, 2014) where confirmed that, in Rwanda, land holding capacity of small holder farmers own 0.7ha of arable land.

4.1.6 Farming experience for maize producers

Table 4.6: Farming experience

Farming experience	Freq.	Percent
Between 1-10 years	105	50.72
Above 10 years	102	49.28
Total	**207**	**100**

Source: Primary Data collected and analysed by the researcher

For farming experience, the results presented in table 4.6 showed that about 51% of the sampled maize producers were experienced within 1-10 years while 49% were experienced above 10 years of farming experience.

4.2 Estimation of the magnitude and distribution of maize post-harvest losses in Rwanda

Estimating the magnitude and distribution of maize post-harvest losses in Rwanda is an essential step in understanding the challenges and opportunities in the maize value chain. To estimate these losses, a combination of data collection methods and approaches can be employed.

Table 4.3: Estimation of the magnitude and distribution of maize post-harvest losses in Rwanda

PHHL Nodes	stats	Area (Ha)	Production (Kgs)	Quantity sold (Kgs)	Quantity Stored/Consumed (Kgs)	PHHL (Kgs)	PHL (%)
Harvesting	Obs	4.00	4.00	4.00	4.00	4.00	11.77
	Mean	0.91	3,622.25	3,279.98	306.32	278.92	
	SD	0.61	2,671.87	2,484.14	250.87	259.60	
	Min	0.40	1,680.00	1,545.60	151.20	109.20	
	Max	1.80	7,560.00	6,955.20	680.40	665.28	
Transportation	N	12.00	12.00	12.00	12.00	12.00	22.82
	Mean	1.46	6,142.50	5,651.10	552.83	540.54	
	SD	0.47	1,964.12	1,806.99	176.77	172.84	
	Min	0.50	2,100.00	1,932.00	189.00	184.80	
	Max	2.00	8,400.00	7,728.00	756.00	739.20	
Drying	N	28.00	28.00	28.00	28.00	28.00	10.45
	Mean	1.04	3,765.86	3,318.75	284.24	247.54	
	SD	0.54	1,934.10	1,701.15	144.98	125.96	
	Min	0.05	181.00	159.28	13.58	11.77	
	Max	2.00	7,240.00	6,371.20	543.00	470.60	
Threshing	N	103.00	103.00	103.00	103.00	103.00	18.39
	Mean	1.24	5,122.05	4,704.04	451.96	435.59	
	SD	0.60	2,487.27	2,291.49	224.63	222.55	
	Min	0.15	630.00	579.60	56.70	55.44	
	Max	2.50	10,500.00	9,660.00	945.00	924.00	
Winnowing, storing	N	2.00	2.00	2.00	2.00	2.00	23.58
	Mean	1.58	6,513.50	5,967.08	576.71	558.62	
	SD	1.73	7,419.67	6,861.93	681.21	673.54	
	Min	0.35	1,267.00	1,114.96	95.03	82.36	
	Max	2.80	11,760.00	10,819.20	1,058.40	1,034.88	
Storage	N	58.00	58.00	58.00	58.00	58.00	12.98
	Mean	1.13	4,340.03	3,906.70	358.30	307.55	
	SD	0.51	2,042.00	1,866.99	181.91	172.24	
	Min	0.25	905.00	796.40	67.88	58.83	
	Max	2.50	10,500.00	9,660.00	945.00	924.00	
	N	207.00	207.00	207.00	207.00	207.00	

PHHL Nodes	stats	Area (Ha)	Production (Kgs)	Quantity sold (Kgs)	Quantity Stored/Consumed (Kgs)	PHHL (Kgs)	PHL (%)
Total overall PHHL	Mean	1.19	4,763.11	4,332.84	407.27	378.52	15.98
	SD	0.57	2,387.54	2,201.15	217.20	216.81	
	Min	0.05	181.00	159.28	13.58	11.77	
	Max	2.80	11,760.00	10,819.20	1,058.40	1,034.88	
	CV	0.48	0.50	0.51	0.53	0.57	

Source: Adopted by the researcher, 2023

From the above table, the study findings showed the Post-harvest Losses of Maize at different nodes varied from 10.43% to 23.58% respectively. It was found that on average, PHL in Nyagatare district is about 15.98%. The study findings also revealed that 11.77% of the maize losses accrued during harvesting stage, followed by PHL of 22.82% that may be accrued during transportation. This higher level of Post-harvest losses (PHL) is associated due to poor transportation facilities that can significantly impact the quantity and quality of maize. Poor transportation practices and infrastructure can lead to various losses at different stages of the supply chain.

Furthermore, the research findings showed that 10.45% of the maize is lost during drying process. This is to indicate that most of farmers in Nyagatare district use several methods of drying maize, each with its own advantages and considerations. The choice of method often depends on factors such as available resources, scale of production, weather conditions, and the desired level of control over the drying process. For example, during the survey as prescribed in the above headings, sun drying is a traditional and widely used method. Maize is spread out in a thin layer on clean, flat surfaces like concrete slabs, mats, or plastic sheets. It is left to dry in the sun. Regular turning of maize kernels is necessary to ensure even drying. This method is cost-effective but depends on weather conditions. In the same vein, the study findings revealed that about 18.39% of the maize PHL accrued during Threshing, 23.58% of the PHL was recorded at the node of winnowing, sorting and grading. Post-harvest losses (PHL) recorded at the nodes of winnowing, sorting, and grading can have significant implications for maize quality and overall food security. These post-harvest operations are crucial for ensuring that the maize is of high quality and free from contaminants. For example, Post-harvest losses (PHL) recorded at the nodes of winnowing, sorting, and grading can have significant implications for maize quality and overall food security. These post-harvest operations are crucial for ensuring that the maize is of high quality and free from contaminants. Additionally, it’s interesting to note that only 12.98% of the maize post-harvest losses (PHL) were recorded at the storage stage. This suggests that the storage practices for maize in the specific context where this data was collected are relatively effective compared to other stages in the maize value chain. However, it's still important to examine the causes and factors contributing to these losses, even if they are relatively low, in order to further improve and minimize them and by overall, the maize post-harvest losses in Nyagatare district is 15.98% respectively. This low value of PHL in Nyagatare district is associated with the Proper Storage Practices where farmers or stakeholders involved in maize storage may be employing good storage practices, such as using hermetic bags, silos, or other suitable storage facilities, which help protect maize from pests, moisture, and mold. In partial conclusion, the estimation of maize post-harvest losses in Rwanda requires a multifaceted approach that combines various data collection methods, engages local knowledge, and utilizes modern technologies. These findings are invaluable for creating targeted interventions, policies, and practices that reduce losses, improve food security, and enhance the income of maize producers in Rwanda.

4.3 Estimation of the economic impact of maize post-harvest losses on individual farmers

Evaluating the economic impact of maize post-harvest losses (PHL) on individual farmers' revenues is crucial for understanding the financial implications of inefficient post-harvest practices and the potential benefits of reducing those losses.

Table 4.4: Economic impact of maize post-harvest losses on individual farmers

Cooperative Name	stats	Price (Rwf/Kgs)	Expected Income	Economic Losses	Actual benefits
CAMARU	N	19	19	19	19
	Mean	350.00	2,215,057.90	353,966.3	1,861,091.65
	SD	0	955,060.82	84,045.35	871,015.46
	Min	350.00	735,000.00	64,680.00	670,320.00
	Max	350.00	4,116,000.00	362,208.00	3,753,792.00
CODPCUM	N	33	33	33	33
	Mean	350.00	2,082,945.50	332,854.7	1,750,090.81
	SD	0	933,156.86	82,117.80	851,039.05
	Min	350.00	367,500.00	32,340.00	335,160.00
	Max	350.00	3,675,000.00	323,400.00	3,351,600.00
KOABITADU	N	23	23	23	23
	Mean	350.00	1,415,673.90	226,224.7	1,189,449.21
	SD	0	548,332.30	48,253.24	500,079.06
	Min	350.00	367,500.00	32,340.00	335,160.00
	Max	350.00	2,646,000.00	232,848.00	2,413,152.00
COOPAMA	N	80	80	80	80
	Mean	362.00	1,731,157.10	276,638.9	1,454,518.20
	SD	14.79	838,308.33	73,341.34	768,443.24
	Min	350.00	220,500.00	19,404.00	201,096.00
	Max	380.00	3,675,000.00	323,400.00	3,351,600.00
CODAR	N	25	25	25	25
	Mean	377.60	1,346,726.90	215,207.0	1,131,519.94
	SD	12.00	584,082.35	37,965.35	546,116.99
	Min	320.00	68,780.00	4,470.70	64,309.30
	Max	380.00	2,613,640.00	169,886.60	2,443,753.40
KOTEBARU	N	27	27	27	27
	Mean	320.00	1,199,158.50	191,625.5	1,007,532.97
	SD	0	631,369.86	41,039.04	590,330.82
	Min	320.00	231,680.00	15,059.20	216,620.80
	Max	320.00	2,316,800.00	150,592.00	2,166,208.00
Total of overall average	N	207	207	207	207
	Mean	354.06	1,680,781.70	268,588.9	1,412,192.78
	SD	18.72	843,597.98	75,971.95	770,308.94
	Min	320.00	68,780.00	4,470.70	64,309.30
	Max	380.00	4,116,000.00	362,208.00	3,753,792.00

Source: Adopted by the researcher, 2023

By conducting a comprehensive evaluation of the economic impact of maize post-harvest losses on individual farmers' revenues, you can highlight the financial benefits of implementing loss-reduction strategies. This information can be instrumental in motivating farmers to adopt improved post-harvest practices and in guiding policy decisions aimed at enhancing food security and rural livelihoods. From the study findings presented by cooperative maize producers, It was found that CAMARU cooperative is the leading one to have highest lost in terms of Revenue with economic loss of 353,966 Frws while the least cooperative to have less economic loss is KOTEBARU with 191,625 Frws while on average the economic losses due to maize Post Harvest Losses at different stage was found to be 268,588 Frws. In this regards, higher post-harvest losses (PHL) of maize have several negative implications for economic losses, which can affect not only individual farmers but also entire communities and nation.

From this view, higher levels of PHL, which stands for Post-Harvest Losses, can have significant implications for economic losses in the agricultural sector. Post-Harvest Losses refer to the quantitative and qualitative losses of food and agricultural products that occur between the time of harvest and the point of final consumption. These losses can occur due to a variety of factors, and when they are extensive, they can lead to economic consequences for several reasons like reduced food availability. Post-harvest losses can significantly reduce the quantity of food available for consumption and sale. This can lead to food scarcity and result in increased food prices, which can adversely affect consumers' purchasing power and food security.

Secondary, PHL could lower also the Income for Farmers. When farmers lose a significant portion of their harvested crops due to post-harvest losses, they earn less income from their agricultural activities. This can result in reduced livelihoods and economic hardships for farming communities. Therefore, Efforts to reduce post-harvest losses through better storage and transportation practices, improved packaging, and increased access to technology and knowledge can help mitigate these economic implications. By minimizing these losses, resources are used more efficiently, and the economic viability of the agricultural sector is enhanced, which, in turn, can contribute to overall economic growth and food security.

4.4 Farmers’ perception on policy and intervention strategies for reducing maize post-harvest losses in Rwanda with a focus on cost-effectiveness measures.

Studying farmers' perceptions of policy and intervention strategies for reducing maize post-harvest losses in Rwanda with a focus on cost-effectiveness measures is a valuable research topic. Farmers' insights can help shape effective policies and interventions.

4.4.1Post-harvest handling and storage technology dissemination

Post-harvest handling and storage technology dissemination is the process of sharing and promoting effective practices, techniques, and technologies for the preservation and management of harvested agricultural produce. This dissemination aims to reduce post-harvest losses, maintain product quality, and enhance the shelf life of crops. It is a critical component of agricultural extension and rural development efforts.

4.4.1.1 Materials of maize harvesting

Maize harvesting involves the use of various materials and equipment to efficiently gather mature maize crops. These materials and equipment can vary based on the scale of farming and the available resources.

Table 4.7: Materials of maize harvesting

Materials of maize harvesting	Freq.	Percent	Cum.
Tarpaulins	25	12.08	12.08
Other materials (specify)	76	36.71	48.79
Bare ground	106	51.21	100
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Table 4.7 pertained to distribution of materials used in maize harvesting practice in Nyagatare district. Findings indicated that 51% of sampled respondents used bare ground, 37% of respondents used other materials while only 12.1% of sampled used tarpaulins in harvesting stage. The findings are in line with the report conducted PASP, 2015 cited in (Bendito & Twomlow, 2015) where a total of 3,045 tarpaulins (plastic sheets) have also been distributed to some of the cooperative members while one cooperative producing maize on 830 ha of consolidated land in Nyagatare district benefited from 49 temporary drying shelters.

4.4.1.2 Transportation of maize after harvesting

The transportation of maize after harvesting is a crucial step in the post-harvest handling process, ensuring that the harvested maize is moved from the field to storage facilities, processing centers, markets, or other destinations. The efficiency and care in transportation can significantly impact the quality and value of the maize.

Table 4.8: Transportation of maize after harvesting

Transportation of maize after harvesting	Freq.	Percent	Cum.
Yes	8	3.86	3.86
No	56	27.05	30.92
After some days	5	2.42	33.33
Shelled and sold off in garden	131	63.29	96.62
Shelled in garden and transported home	7	3.38	100
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Maize producers from Nyagatare district were asked questions related to transportation of maize produces after harvesting. The summary of descriptive statistics indicated that only 3.9% of maize growers transport their produces directly after harvesting while 27.1% did not. These led to farmers to adopt other Post-harvest techniques where 63.3% of sampled farmers shell and sold their maize off in garden, 3.4% of shell in garden and transport at their home land while only 2.4% transport their maize produce after some days.

4.4.1.3 Modes of transport and equipment used in transportation after harvesting

The modes of transport and equipment used in the transportation of agricultural produce, including maize, after harvesting, can vary depending on factors like the scale of production, infrastructure, and local conditions.

Table 4.9: Modes of transport and equipment used in transportation after harvesting

Modes & equipment of transport	**Freq.**	**Percent**	**Cum.**
Tractor	5	2.42	2.42
Bicycle	96	46.38	48.79
Head	10	4.83	100
Other (wheel barrow, basket, ..)	96	46.38	95.17
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Table 4.9 points out the summary of descriptive statistics regarding modes and equipment used in maize transportation after harvesting. The findings revealed that 46.4% of the total sampled maize growers use bicycle and other modes like wheel barrow, motor cycle, trucks and basket gunny during transportation, 4.8% of sampled farmers used their own head while only 2.4% use tractors as mechanized equipment to reduce Post-harvest losses in transportation.

4.4.1.4 Equipment used in maize drying in Nyagatare district

In Nyagatare district, as in many agricultural regions, equipment used for maize drying typically includes a range of tools and facilities to reduce the moisture content of freshly harvested maize. Proper drying is essential to prevent mold growth, ensure storage stability, and maintain the quality of maize. The specific equipment used can vary depending on the scale of production and the available resources.

Table 4.10: Equipment used in maize drying in Nyagatare district

Equipment used in maize drying	Freq.	Percent	Cum.
Sun heat (maize spread on tarpaulin)	27	13.04	13.04
Sun heat (maize spread on bare	141	68.12	81.16
Ground	32	15.46	96.62
Sun heat (maize spread on roof top)	7	3.38	100
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Maize producers from the study area were asked questions related to equipment used in maize drying to reduce Post-harvest losses that may accrued in the drying stage node. The results from the field survey conducted in 2018 revealed that about 68% of all sampled maize growers use sun heat (maize spread on bare), 15.5% of the producers use the ground, 13% use the sun heat (maize spread on tarpaulins) while only 3.4% of the sampled farmers used the sun heat (maize spread on roof top) respectively.

4.4.1.5 Methods of maize shelling used by maize growers in Nyagatare district

In Nyagatare district and similar agricultural regions, maize growers use various methods for shelling or removing the kernels from the maize cobs. The method employed often depends on factors like the scale of farming, available resources, and traditional practices.

Table 4.11: Methods of maize shelling used by maize growers in Nyagatare district

Methods of maize shelling	Freq.	Percent	Cum.
Maize Sheller	12	5.8	5.8
Beating with sticks	15	7.25	13.04
Hand shelling	90	43.48	56.52
Maize thresher	83	40.1	96.62
Others (specify)	7	3.38	100
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Table 4.11 indicated the methods of maize shelling used by maize growers in Nyagatare district. The findings revealed that about 43.5% of the sampled maize producers used hand shelling, 40.1% used the maize thresher, 7.3% use traditional shelling (beating with sticks) while only 5.8% use maize Sheller. There are some farmers who are using other methods maize shelling including stone rub during the Post-harvest handing operations to reduce Post-harvest losses. The stone can be, any stone, collected from the area given it has groves. It doesn't crush and spread maize yield. More force is required to thresh maize of larger cob size. Stone-rub occasionally rubs the hands of the individuals in the operation.

4.4.1.6 Materials used in maize storing

Maize storing involves the use of various materials and equipment to safely and effectively store maize for extended periods, preserving its quality and preventing post-harvest losses. The choice of materials and methods depends on factors like the scale of storage, local conditions, and resources.

Table 4.12: Materials used in maize storing

Materials	Freq.	Percent	Cum.
Traditional gunny bag	160	77.29	77.29
Hermetic storage (specify)	18	8.7	85.99
Plastic silo	23	11.11	97.1
Super grain bag (multi-layer)	6	2.9	100
Polyethylene storage bag	0	0	
Metallic silo	0	0	
Others (specify)	0	0	
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Respondents from the study area were subjected questions related to Materials used in maize storing to reduce Post-harvest losses to boost the economic status of maize producers from the Nyagatare district. As illustrated in table 4.12, the findings indicated that about 77.3% of the total sampled farmers use traditional gunny bags, followed by 8.7% of maize farmers using hermetic storage, a little bite followed by 11.1% of the maize producers who are using plastic silos and finally 2.9% of respondents who habitually using super grain bags (multi-layer) system. These findings agree with the report of USAID, 2013 where PHHS partnered with MINAGRI to improve on-farm storage through the use of hermetic bags. In addition, 953 agro-dealers and 563 lead farmers were trained in May 2013 in the use of two different airtight bags which is followed by national hermetic bag opening day was held in June 2013, with the purpose of showing farmers and traders the impact that the hermetic bags have on controlling insect infestation and maintaining stable moisture levels in grain.

4.4.1.7 Methods of pest control in storage in Nyagatare district

Effective pest control in maize storage is crucial for preventing post-harvest losses and maintaining the quality of the stored maize. Various methods can be employed to control and manage pests in storage facilities.

Table 4.13: Methods of pest control in storage

Methods of pest control	Freq.	Percent	Cum.
Fumigants	136	65.7	65.7
Others (specify)	71	34.3	100
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Table 4.13 pertained to distribution of maize growers by methods used for pest control in maize storage. The findings showed that about 65.7% of the sampled famers use fumigants and only 34.3% use other methods of pest control in the store like cleanliness of the store before storage operations.

4.4.1.8 Time of maize storage

The length of time maize can be safely stored depends on various factors, including the initial moisture content of the maize, storage conditions, and the presence of pests or diseases. In general, maize can be stored for different durations, ranging from a few months to several years, but the exact time can vary based on the following considerations.

Table 4.14: Time of maize storage

Variable	Obs	Mean	Std. Dev.	Min	Max
Time of maize storage (months)	207	5.830918	4.484646	1	20

Source: Primary Data collected and analysed by the researcher

Farmers from Nyagatare district were asked to indicate time used in maize storage before trading. The summary of descriptive statistics showed that time elapsed varied between 1 to 20 months while on average; at least 6 months were used to store the maize produce under store and warehouse before selling. This period is necessary for small scale farmers because it can increase the markets price as expected by the commodity supplier.

4.4.1.9 Knowledge on maize quality parameters for maize producers

Maize quality parameters are essential for maize producers to understand and monitor to ensure that their maize meets market and consumer standards.

Table 4.15: Knowledge on maize quality parameters

Knowledge on maize quality	Freq.	Percent	Cum.
No	48	23.19	23.19
Yes	159	76.81	100
Total	**207**	**100**	
Types of parameters affecting maize quality	Freq.	Percent	Cum.
Missing system	48	23.19	23.19
Aflatoxin	31	14.98	38.16
Broken grains	8	3.86	42.03
Damaged grains	6	2.9	44.93
Discolored grains	12	5.8	52.17
Foreign matters	37	17.87	70.05
Immature grains	5	2.42	72.46
Moisture content	32	15.46	87.92
Quantity of broken grains	5	2.42	90.34
Size of the grain	17	8.21	100
Total	**207**	**100**	

Source: Primary Data collected and analysed by the researcher

Based on findings presented in table 4.15 below, maize growers in Nyagatare district were asked questions related to knowledge of maize quality parameters. As shown, about 77% of the total surveyed maize farmers know the maize quality parameters while 23% of the farmers did not. Based on knowledge and skills on maize quality parameters, 15% of the surveyed farmers know aflatoxin, 18% of the sampled farmers know foreign matters from the maize grains and 15.5% of the surveyed respondents know the moisture content of the maize produces. In addition, 8.2% of the maize growers know the measurement of the size of the grain, 6% know the discolored grains from the sample in the bags, 3.9% of the farmers know to identify the broken grains, 2.9% of the maize growers know separate the damage grains from the undamaged grains and 2.4% know to identify immature grains and quantity of broken grains respectively.

4.4.1.10 Access to government support

This section describes the access government services like access to extension services, access to markets information for maize producers in Nyagatare district as the case of interest. The findings showed that 86% of the total surveyed maize growers have access to extension services while 14% did not. In addition the findings also revealed that about 88% of the surveyed farmers have access to markets information while 12% of remaining did not. Results also from the field survey showed that 61.4% have knowledge and access to government policy while their counterfactual of 36.2% did not. Finally the surveyed results showed that 78% of the total sampled respondents have Knowledge and access to Local and NGO's activities mean while 22% of the reaming farmers did not. These results agree with the report of (Kiptot *et al.*) in 2016 cited in (Franzel *et al.*, 2019) where their findings' study clearly demonstrated that the use of volunteer farmers in extension which is an approach that should be highly promoted as it has the potential to spread technologies to many farmers within a short period of time. They reported that VFTs were able to reach an average of 24 farmers per month and an average of 217 farmers per trainer within a period of 3.5 years. This is indeed remarkable considering that they face many challenges when undertaking their dissemination activities (Franzel *et al.*, 2019).

4.4.1.11 Estimation of PHHL at farmer level in Nyagatare district

Estimating post-harvest losses (PHHL) at the farmer level in Nyagatare district or any agricultural region involves assessing the quantity and quality of agricultural produce lost during the post-harvest stages.

Table 4.16: Estimation of PHHL at farmer level in Nyagatare district

PHHL at Transportation node	Freq.	Percent
Around 50%	5	2.44
Between 30%-49%	16	7.8
Between 10%-29%	24	11.71
Between 5%-9%	40	19.51
Between 1%-4%	119	58.05
No (0%)	1	0.49
Total	**205**	**100**
PHHL at storage node	Freq.	Percent
Above 50%	15	7.25
Between 30%-49%	32	15.46
Between 10%-29%	35	16.91
Between 5%-9%	81	39.13
Between 1%-4%	43	20.77
At 0%	1	0.48
Total	**207**	**100**

Source: Primary Data collected and analysed by the researcher

Farmers from Nyagatare district were asked questions related to Post-harvest handling losses (PHHL) at farm levels. The most PHHS nodes with high losses occurrence were the transportation node and storage key node. For transportation node, the PHHL ranged between 1% - 4% of the total harvested maize were loosen during transportation reported by 58.1% of the total sampled farmers, followed by those 19.5% with losses varying between 5% -9% of harvested maize. There are also farmers who are wasting maize varying from 10% -29% of PHHL, 30% - 49% of maize PHHL and 2.44% who are losing around 50% of maize PHHL and only 0.49% has no loss. Furthermore, during storage process, high PHHL accrued at this stage ranged between 5% - 9% as reported by 39.1% of the total sampled respondents, followed farmers whose PHHL ranged between 1% - 4% indicated by 20.8%, 10% - 29% of PHHL reported by 16.9%, 30% - 49% reported by 15.5% and 7.3% of farmers have faced with PHHL above of 50% of the total stored maize in warehouse. The study findings indicated that only 0.48% of the sampled farmers have no loss during storage process due to adequacy of technology adoption of PHHS practice like use of pallets, well cleaned stores and use appropriate fumigants.

4.4.2 Econometric findings

In this section, the study used the multiple linear regressions to analyse the determinants of Post-Harvest Losses of Maize in Nyagatare District, Rwanda. The model was used in a manner where each independent variables was analysed individually while holding other variables constant. The study used the Ordinary Least Square (OLS estimator). Study of post-harvest losses covers many aspects, in view of the wide range of (a) products involved; (b) successive operations in the post-harvest system; (c) causes of losses; and (d) pests and other food parasites, not to mention; (e) physical, technical, and economic and other conditions that aid and abet the action of the agents of deterioration, consequently increasing losses.

4.4.2.1 Influence of storage duration of maize on its postharvest losses

The storage duration of maize has a significant influence on its post-harvest losses. Post-harvest losses in maize can occur due to various factors, including pests, fungi, moisture, temperature, and the quality of storage facilities. The longer maize is stored, the greater the risk of experiencing losses, and the specific effects of storage duration on these losses can be understood for instance on maize quality degradation. This variable was individually analyzed as follows: $\mathbf{Y = \beta_0 + \beta_1 X_1 + U_1}$

Table 4.17: Influence of storage duration of maize on its postharvest losses in Nyagatare

Do you experience any Post-harvest losses	*Coef.*	*Std. Err.*	*t*	*P>/t/*
Influence of storage duration of maize on its postharvest losses				
Time used to store the maize before selling	-0.02446	0.002477	-9.88	0.000
_cons	1.103995	0.018205	60.64	0.000
Number of Obs		=		207
F(1, 205)		=		97.53
Prob > F		=		0.000
R-squared		=		0.3224
Adj R-squared		=		0.3191
Root MSE		=		0.15944
Source	SS	df	MS	

Model	2.479401	1	2.479401
Residual	5.21142	205	0.025422
Total	7.690821	206	0.037334

Note: *, ** and *** are significance level at 10%, 5% and 1% respectively

Source: Primary Data collected and analysed by the researcher

Table 4.17 indicated the econometric findings from the linear regression model to determine determinants of maize post-harvest losses in Nyagatare District, Rwanda. The results from MLR results on the Influence of storage duration of maize on its postharvest losses showed that only time store the maize before selling was statistically significant at 1% and 5% level of significance respectively (p-value of 0.000<0.001) to influence maize post-harvest losses for small scale maize producers in Nyagatare District, Rwanda. As *priori* expectation, the results indicate negative relationship between times used to store the maize before selling and experience in Post-harvest losses affected maize post-harvest losses in the study area. The model fit with one explanatory variable indicated moderate coefficient of determination of R^2 is 32.24% explained by time used to store maize in warehouse. This implies that they are other external factors that may influence storage duration of maize on its postharvest losses. This means that one unit year increase in the time to store maize in the store, the production of maize stored decreased by 0.245 percent of the total maize stored in the warehouse and led to Post-harvest losses of 0.245% for maize producers (holding other independent variables constant). This is an implication that long time of maize storage may deteriorate the physical and chemical composition of maize grains including color, size for physical parameters and floor grains for chemical composition. In addition, Postharvest loss accounts for direct physical losses and quality losses that reduce the economic value of crop, or may make it unsuitable for human consumption due to micro-organism. These results are coherent with the research conducted by (Kumar & Kalita, 2017) confirmed that during the crop transition from farm to consumer, it has to undergo several operations such as harvesting, threshing, cleaning, drying, storage, processing and transportation. During this movement, crop is lost due to several factors such as improper handling, inefficient processing facilities, biodegradation due to microorganisms and insects, etc (Vales *et al.*, 2014).

4.4.2.2 Impact of methods of postharvest handling and storage on postharvest losses of maize

The methods of post-harvest handling and storage have a significant impact on post-harvest losses of maize. Effective post-harvest practices can help minimize losses and preserve the quality and quantity of maize. This variable was individually analyzed for each PHHS method as follows: $\mathbf{Y = \beta_0 + \beta_2 X_2 + U_2}$

Table 4.18: Impact of methods of PHHS on postharvest losses of maize

Do you experience any Post-harvest losses	Coef.	Std. Err.	t	P>|t|
Impact of methods of postharvest handling and storage on postharvest losses of maize				
Materials used in harvesting	**0.048794**	**0.02364**	**2.06**	**0.04****
Transportation after harvesting	-0.02662	0.015669	-1.7	0.091*
Mode of transport of produce	**0.107477**	**0.023538**	**4.57**	**0.000*****
Equipment to carry maize after harvesting	0.003774	0.010663	0.35	0.724
Methods of maize drying	-0.00381	0.014266	-0.27	0.789
Equipment used in maize drying	**0.076291**	**0.024583**	**3.1**	**0.002****
Maize Shelling method	**-0.03655**	**0.017803**	**-2.05**	**0.041****
Sorting before storing	-0.01088	0.038031	-0.29	0.775
Measurement of moisture cont before storage	-0.0382	0.030216	-1.26	0.208
Materials used in maize storage	**-0.02046**	**0.008343**	**-2.45**	**0.015****
Pest control in maize storage	-0.04194	0.03283	-1.28	0.203
_cons	0.692337	0.094771	7.31	0.000
Number of Obs		=		207
F(11, 195)		=		7.04
Prob > F		=		0
R-squared		=		0.2842
Adj R-squared		=		0.2438
Source	SS	df	MS	
Model	2.185362	11	0.198669	
Residual	5.505459	195	0.028233	
Total	7.690821	206	0.037334	

Note: *, ** and *** are significance level at 10%, 5% and 1% respectively

Source: Primary Data collected and analysed by the researcher

Findings presented in table 4.18 indicated the econometric results from multiple linear regression models with dependent variable of experience any Post-harvest losses in Nyagatare district. The findings from MLR on the impact of methods of postharvest handling and storage on postharvest losses of maize showed that only materials used in harvesting, transportation after harvesting, mode of transport of produce, equipment used in maize drying, maize Shelling method and materials used in maize storage affected maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda and were statistically significant at 1%; 5% and 10% level of significance respectively for small holder maize growers in Nyagatare district. The model fit suggested a moderate power. The coefficient of determination R^2 is 28.42%, indicating that 28.42% of the total variation in the Post-harvest losses is due to poor methods of PHHS practices in Nyagatare district.

The results from the from MLR model showed that materials used in harvesting by small holder maize farmers was statistically and significantly affected the affected maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda at 5% level of significance. Unexpectedly, the results indicate positive relationship between materials used in harvesting and the farmer experienced any Post-harvest losses in maize production chain in the study area. The positive correlation implies that most of maize producers are aware to prepare the harvesting period by searching all needed materials to increase the quality of maize produces including bags, machete and tarpaulins to reduce PHHS losses. Harvesting is considered as the first step in the grain supply chain and is a critical operation in deciding the overall crop quality. In the countries under development, crop harvesting is performed mainly manually using hand cutting tools such as sickle, knife, scythe and cutters which are done manually. Thus due to technology advancement now days where inauguration of combine harvesters (mechanically) in maize harvesting reduced the Post-harvest losses in Nyagatare district. The findings are in line with the research conducted by (Kumar & Kalita, 2017) confirmed that harvesting timing and method (mechanical vs. manual) are two critical factors dictating the losses during the harvesting operations(Bradford *et al.*, 2018; Danso *et al.*, 2018).

The results from the MLR model showed that transportation after harvesting by small holder maize farmers was statistically and significantly affected the maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda at 10% level of significance. Expectedly, the results indicated negative relationship between transportation after harvesting and the farmer experienced any Post-harvest losses in maize production chain in the study area. The negative correlation implies that most of maize producers do not transport maize produces from the farm location to home land and these increase the level of PHHS losses. Findings also from MLR model showed mode of transport of produce affected positively the maize Post-harvest losses for small scale maize producers statistically significant at 1% and 5% level of significant. The positive correlation implies that there is an economic status when a transportation mode on PHHS chain is maintained properly. An increase of one more poor transportation practice of maize is used, Post-harvest losses of maize is increased by 1.075 percent (ceteris paribus). Transportation is an important operation of the grain value chain, as commodities need to be moved from one step to another, such as field to processing facilities, field to storage facilities, and processing facilities to market. The lack of adequate transportation infrastructure results in damage of food products through bruising and losses due to spillage. Transportation loses are relatively very low in the developed countries due to better road infrastructure and engineered facilities on the field and processing facilities to load and unload the vehicles rapidly with very little or no damage. At the field level, most of the crop is transported by bicycle, motor cycle, wheel burrow and open truck as well as tractors. The findings agree with the research conducted by (Kumar & Kalita, 2017) where confirmed that grains for self-usage are usually transported in bags from field storage to processing facilities in bullock carts, bicycles, small motor vehicles, or open trucks. Poor road infrastructure along with these improper and poorly maintained modes of transportation results in large spillage and high contamination (Befikadu, 2018; Kumar & Kalita, 2017).

Findings presented in tale 4.18 from MLR model showed that equipment used in maize drying by small holder maize farmers was statistically and significantly affected the maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda at 5% level of significance. Expectedly, findings indicated positive correlation between explanatory and dependent variables; meaning that one additional inappropriate drying equipment is used by maize producers, Post-harvest losses of maize is increased by 0.763% (ceteris paribus). Drying of maize harvested is most important node in Post-harvest chain to maintain moisture content from 20% after direct harvesting to of 13.5% after drying operations which agree with the findings of (Hoque & Hoffmann, 2019) concluded that the safe moisture content for long-term storage of most of the crops is considered below 13%. In Rwandan context, most equipment used in drying stage is cemented ground, tarpaulins, hangar and nuts and sometimes mobile maize dryers for some cooperatives. As apparent from the descriptive analysis, the grains are usually harvested at high moisture content to minimize the shattering losses in the field. Even for the short-term storage (less than 6 months), the moisture should be less than 15% for most of the crops. Inadequate drying can result in mold growth and significantly high losses during storage and milling. Therefore, drying is a critical step after harvesting to maintain the crop quality, minimize storage losses and reduce transportation cost. Drying can be performed naturally (sun or shade drying) or using mechanical dryers. Natural drying or sun drying is the traditional and economical practice for drying the harvested crop, and is the most popular method in developing countries. Grains lying in the open for sun drying are eaten by birds and insects, and also get contaminated due to mixing of stones, dust, and other foreign materials. Unseasonal rains or cloudier weather may restrict the proper drying, and the crop is stored at high moisture, which leads to high losses due to mold growth and these are consistent with the research conducted by (Kumar & Kalita, 2017).

Findings presented in tale 4.18 from MLR model showed that maize shelling method by small holder maize farmers was statistically and significantly affected the maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda at 5% level of significance. Unexpectedly, there is a negative relationship between maize shelling method and the farmer experienced any Post-harvest losses in maize production chain in the study area. one more proper maize Shelling method is used, Post-harvest losses is reduced by 0.37 percent (ceteris paribus). The proper use of maize Sheller increase the quality and safety of maize produced and reduced the spoilage of maize grains and the study suggest the educational improvement to use such technology; the findings agree with (Adejo *et al.*, 2016) who confirmed that there is a need of improving the educational background of maize farmers through adult education to facilitate access to needed information on improved postharvest technologies and their utilization for better value addition to harvested maize.

Findings presented in tale 4.18 from MLR model showed that materials used in maize storage by small holder maize farmers was statistically and significantly affected the maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda at 5% level of significance. Unexpectedly, there is a negative relationship between Materials used in maize storage and the farmer experienced any Post-harvest losses in maize production chain in the study area. One more improved material used in maize storage used up to 0.15 percent level of probability, Post-harvest losses of maize is reduced by 0.205 (ceteris paribus). The negative correlation indicated that there insufficient of advanced technology in maize storage infrastructures like metal silos, cocoons and hermetic bags to reduce Post-harvest losses in storage link. Storage plays a vital role in the food supply chain, and several studies reported that maximum losses happen during this operation (Aulakh *et al.*, 2013; Bala *et al.*, 2010; Majumder *et al.*, 2016). In most of the places, crops are grown seasonally and after harvesting, grains are stored for short or long periods as food reserves, and as seeds for next season. The indigenous storage structures are made of locally available materials (grass, wood, mud etc.) without any scientific design, and cannot guarantee to protect crops against pests for a long time. The study findings agree with the research conducted by (Costa, 2014) estimated losses as high as 59.48% in maize grains after storing them for 90 days in the traditional storage structures (Granary/Polypropylene bags).

4.4.2.3 Impact of farmers' skills and knowledge on preventing maize postharvest losses

Farmers' skills and knowledge play a significant role in preventing maize post-harvest losses. When farmers are well-informed and equipped with the right skills, they can implement effective post-harvest practices that help minimize losses. This variable was individually analyzed as follows: $\mathbf{Y = \beta_0 + \beta_3 X_3 + U_3}$

Table 4.19: Impact of farmers' skills and knowledge on preventing maize postharvest losses

Do you experience any Post-harvest losses	Coef.	Std. Err.	t	P>|t|
Impact of farmers' skills and knowledge on preventing maize postharvest losses				
Knowledge on maize quality parameters	**-0.04501**	**0.032567**	**-1.38**	**0.104***
Knowledge the effect of absence of PHH losses	-0.009	0.0708	-0.13	0.899
Knowledge of poor transportation	**-0.03009**	**0.053058**	**-0.57**	**0.005****
_cons	1.030007	0.054374	18.94	0.000
Number of Obs		=		207
F(3, 203)		=		1.11
Prob > F		=		0.348
R-squared		=		0.1161

Adj R-squared		=		0.105
Root MSE		=		0.19307
Source	SS	df	MS	
Model	0.123606	3	0.041202	
Residual	7.567215	203	0.037277	
Total	7.690821	206	0.037334	

Note: *, ** and *** are significance level at 10%, 5% and 1% respectively

Source: Primary Data collected and analysed by the researcher

Findings presented in table 4.19 indicated the econometric results from multiple linear regression models with dependent variable of experience any Post-harvest losses in Nyagatare district. The findings from MLR on the impact of farmers' skills and knowledge on preventing maize postharvest losses on postharvest losses of maize showed that only two variables Knowledge on maize quality parameters and Knowledge of poor transportation affected maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda and were statistically significant at 5% and 10% level of significance respectively for small holder maize growers in Nyagatare district. The model fit suggested a weak power. The coefficient of determination R^2 is 11.61%, indicating that 11.61%, of the total variation in the Post-harvest losses is due to poor knowledge on PHHS practices in Nyagatare district.

Findings presented in table 4.19 from MLR model showed that Knowledge on maize quality parameters by smallholder maize farmers was statistically and significantly affected the maize post-harvest losses for small-scale maize producers in Nyagatare District, Rwanda at 10% level of significance. Unexpectedly, there is a negative relationship between Knowledge on maize quality parameters and the farmer experienced any Post-harvest losses in maize production chain in the study area. The increases of one unit of Knowledge on maize quality parameters up to 1.04 percent level of probability, the Post-harvest losses reduced by 0.45 percent (other factors being constant). The quality of maize parameters included aflatoxin; broken grains, damaged grains, discolored grains, foreign matters, immature grains; moisture content, quantity of broken grains and Size of the grain deteriorate physical and chemical composition of maize grains. Furthermore, results from MLR model showed that Knowledge of poor transportation by small holder maize farmers was statistically and significantly affected the maize post-harvest losses for small scale maize producers in Nyagatare District, Rwanda at 5% level of significance. Unexpectedly, there is a negative correlation between explanatory and dependent variable, where one unit increase to knowledge about transportation up to 0.05 percent level of probability, the Post-harvest losses reduced by 0.45 percent (other factors being constant). Poor transportation facilities like paved roads and inappropriate used trucks may generate Post-harvest losses for farmers due to long journey. The findings agree with the research conducted by (Alhassan & Kumah, 2018) confirmed that transportation loses could be high if trucks transport the produce for a long journey without covering the bags with tarpaulin.

4.4.2.4 Influence of institutional factors on Post-Harvest economic Losses of Maize in Nyagatare District

Institutional factors can have a profound influence on post-harvest economic losses of maize. These factors encompass government policies, regulations, market structures, and support systems that affect the entire post-harvest value chain. This variable was individually analyzed as follows: $\mathbf{Y = \beta_0 + \beta 4X_4 + U_4}$

Table 4.20: Influence of institutional factors on Post-Harvest economic Losses of Maize in Nyagatare District

Do you experience any Post-harvest losses	Coef.	Std. Err.	t	P>t
Influence of institutional factors on Post-Harvest economic Losses of Maize				
Access to extension services	**-0.01808**	**0.044021**	**0.41**	**0.002****
Access to markets information	**-0.00869**	**0.05815**	**0.15**	**0.081***
Access to government policy	-0.01812	0.026764	-0.68	0.499
Access to bank agro-credits	**-0.0375**	**0.5010**	**-0.07**	**0.04****
Access to Local and international NGO's activities	-0.04205	0.046436	-0.91	0.366
Trainings on Good Agriculture Practices (GAP)	-0.10972	0.270705	-0.41	0.685

Trainings on pest and diseases control	0.202421	0.328142	0.62	0.537
Trainings on Farm records	0.259653	0.458063	0.57	0.571
Trainings on Quality and safety	-0.08911	0.487033	-0.18	0.855
Trainings on sorting and Grading	0.276922	0.534217	0.52	0.604
Distance to nearest road	0.0594	0.0395	1.5	0.433
Distance to nearest market	**0.0004**	**0.0012**	**0.35**	**0.026****
Distance to nearest financial institutions	0.0055	0.0149	0.37	0.71
_cons	1.009403	0.044985	22.44	0.000
Number of Obs		=		207
F(4, 202)		=		0.78
Prob > F		=		0.5362
R-squared		=		0.1453
Adj R-squared		=		0.1242
Root MSE		=		0.19363
Source	SS	df	MS	
Model	0.117694	4	0.029423	
Residual	7.573127	202	0.037491	
Total	7.690821	206	0.037334	

Note: *, ** and *** are significance level at 10%, 5% and 1% respectively

Source: Primary Data collected and analysed by the researcher

The results presented in table 4.20 indicated the econometric results from multiple linear regression models with dependent variable of farmer' experienced Post-harvest losses in Nyagatare district. The findings from MLR on the influence of institutional factors on Post-Harvest economic Losses of Maize in Nyagatare District showed that only access to extension services, access to markets information, access to bank credits, trainings on PHHS practices and distance to nearest market affected maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda and were statistically significant at 5% and 10% level of significance respectively for small holder maize growers in Nyagatare district. The model fit suggested a weak power. The coefficient of determination R^2 is 14.5%, indicating that 14.5% of the total variation in the Post-harvest losses is due to small number of institutional support on PHHS practices in Nyagatare district.

With reference to table 4.20, the findings from MLR showed that access to extension services was the key institutional factor affected Post-Harvest economic Losses of Maize in Nyagatare District statistically significant at 5% level of significance in the study area. Expectedly, the results indicated the negative relationship between accessibility of extension services and farmer's experienced any Post-harvest losses. In relation to extension services, the results show that one additional meeting with extension service providers up to 0.02% level of probability to meet an extension agent at 5%; the likelihood for farmers to incur Post-harvest losses is decreased by 0.181% (other factors being constant). One of the most important roles of extension service is to raise farmer's awareness about agricultural productivity through providing them important information related to adoption of agricultural technologies and dissemination of better practices on Post-harvest handling management. According to (Kassie *et al.*, 2009) cited in (Owombo *et al.*, 2012), in most cases, extension workers establish demonstration plots where farmers get hands-on learning and can experiment with new farm technologies which enhance adoption of new technologies. The results of the study therefore confirm that better information dissemination through extension workers could enhance adoption of organic fertilizer by improving knowledge about the advantage of new technology; thus, for a given household, the more the frequency of meeting extension workers, the higher the likelihood of organic fertilizer adoption. The finding was in line with (Kassie *et al.*, 2009) cited in (Owombo *et al.*, 2012). They argued that farmers who have regular contact with agricultural experts are more motivated to participate in agricultural technology adoption due to intensive information they may get from the experts.

Findings from MLR showed that access to markets information was the key institutional factor affected Post-Harvest economic Losses of Maize in Nyagatare District statistically significant at 5% level of significance in the study area. Expectedly, the results indicated the negative relationship between accessibility markets information and farmer's experienced any Post-harvest losses. The results show that one unit increase to accessibility of markets information up to 0.81 percent level of probability at 10%; the likelihood for farmers to incur Post-harvest losses is decreased by about 0.087% (other factors being constant). Obtaining proper market information seems to become more important in Post-harvest value chain based on when products to go distant markets, when products are customer-specific, when competition is increasing, and when quality (and quality control) is becoming more important to boost the competitive markets price. Thus, smallholders seeking to become participants in high value supply chains are faced with more serious information problems for maize producers in the study area. For Rwandan agriculture sector, specifically for small scale maize producers, gaining access to market information is important for the efficient operation of the interregional grain trade. The availability of market information and the ability of grain traders to use it efficiently affect the extent to which they can exploit profitable spatial arbitrage opportunities. The findings are coherent with the results drawn by (Asfaw *et al.*, 2011) cited in (Legese & Fadiga, 2014) found that producers also need market information to make their production and marketing decisions, while policymakers need it to make effective policy decisions. Their study also pointed out that traditionally, grain traders have relied on informal sources of market information, such as friends and neighbours who visited markets, friends or traders in different markets, market visits, etc(Dejene, 2017; Legese & Fadiga, 2014).

Results from the probit model presented in table 4.20 showed that distance to nearest markets was the institutional factor affected Post-Harvest economic Losses of Maize in Nyagatare District statistically significant at 5% level of significance in the study area. Market distance as expected, the distance of farmers' residence from the nearest market centre was significantly and positively associated with Post-Harvest losses of Maize in at 5% level of significance. The result of the odds-ratio indicated that, other factors being constant, as the distance of the farmer's residence from the nearest market centre increases by one kilometer up to 0.26 percent level of probability, the probability of incurring Post-Harvest losses is increased by 0.004 percent. This is due to the fact that as the farmers reside far from the nearest market they face high transportation cost for selling their output and also have low market information which can increase the level of probability to have a PHHL during transportation note to the nearest markets. These findings are in line with this study's findings by (Hengsdijk & De Boer, 2017) and (Tadesse & Fayera, 2018) concluded that Three major factors associated with post-harvest losses were the distance of the household dwelling to the nearest market, the distance of the household dwelling to the main road, and average annual rainfall.

Results from MLR model presented in table 4.20 revealed that access to agro-credits was the institutional factor that affects Post-Harvest Losses of Maize in Nyagatare District and was statistically significant at 10% level of significance in the study area. Unexpectedly, findings indicated the negative correlation between agro-credits accessibility and Post-Harvest economic Losses of Maize in Nyagatare District statistically significant at 10% level of significance in the study area, Rwanda. The findings from MLR model indicated that a farmer to access an agro-credit, the probability of incurring Post-Harvest Losses of Maize is decreased by 0.375% (holding other factors constant). The credits accessibility enhances the farmer's ability to afford Post-harvest equipment like tarpaulins, construction and rehabilitation of existing warehouse and investment in value addition of maize produces.

The credits accessibility enhances the farmer's ability to afford Post-harvest equipment like tarpaulins, construction and rehabilitation of existing warehouse and investment in value addition of maize produces. It enhances also the producer's capacity to pay labor cost used in transportation accrued in marketing value chain of the commodity. Having access to formal (bank and microfinance) and informal saving institutions create a good opportunity for farmers to have an asset and to purchase different agricultural technologies including Post-harvest technologies (Yehuala *et al.*, 2013). These findings are coherent with the research conducted by (Muzari *et al.*, 2012) also stated that the major option for increased adoption of technology is to overcome the income/capital constraint through increased credit provision. This is consistent with the report of (Akudugu *et al.*, 2012) and (Bekuma *et al.*, 2018).

CHAPTER 5: SUMMARY, CONCLUSION AND SUGGESTIONS

The overall study of this thesis is to analyse the determinants of Post-Harvest economic Losses of Maize in Nyagatare District, Rwanda as the case of interest. Indicating summary, conclusion, and recommendation reached for each specific objective is a crucial task. Here summary, conclusion, and recommendation are a brief and main body of this chapter as indicated in the subheadings.

5.1 Summary of findings

This study was conducted in Nyagatare district of Eastern Province of Rwanda, which is classified amongst high potentiality of maize producers. Therefore, the aim of this study is analyse the determinants of Post-Harvest Losses of Maize in Nyagatare District, Rwanda. Further the study also intends to analyse the influence of storage duration of maize on its postharvest losses, to examine the impacts of methods of postharvest handling and storage on postharvest losses of maize, to assess the impact of farmers' skills and knowledge on preventing maize postharvest losses and to analyse influence of institutional factors on Post-Harvest economic Losses of Maize in Nyagatare District. The cross-sectional survey design employing six maize farming cooperatives and other dairy producers not members of cooperatives from Gicumbi District of Northern Province was adopted. The entire population of this study of 429 maize farming cooperative and the total sample size as preselected is 207 maize producers from the study area. Descriptive statistics, means, SD, frequency and percentage as well as multiple linear regression (MLR) models were used to analysis the result of the study.

Estimation of the magnitude and distribution of maize post-harvest losses in Rwanda

The summary of findings showed the Post-harvest Losses of Maize at different nodes varied from 10.43% to 23.58% respectively. It was found that on average, PHL in Nyagatare district is about 15.98%. The study findings also revealed that 11.77% of the maize losses accrued during harvesting stage, followed by PHL of 22.82% for accrued during transportation, 10.45% of the maize is lost during drying process, 18.39% of the maize PHL accrued during threshing, 23.58% of the PHL was recorded at the node of winnowing, sorting and grading and only 12.98% of the maize post-harvest losses (PHL) recorded at the storage stage. The study findings revealed that low value of PHL in Nyagatare district is associated with the proper storage practices where farmers or stakeholders involved in maize storage may be employing good storage practices, such as using hermetic bags, silos, or other suitable storage facilities, which help protect maize from pests, moisture, and mold. In partial conclusion, the estimation of maize post-harvest losses in Rwanda requires a multifaceted approach that combines various data collection methods, engages local knowledge, and utilizes modern technologies.

Estimation of the economic impact of maize post-harvest losses on individual farmers

From this objective, It was found that CAMARU cooperative is the leading one to have highest lost in terms of Revenue with economic loss of 353,966 Frws while the least cooperative to have less economic loss is KOTEBARU with 191,625 Frws while on average the economic losses due to maize Post Harvest Losses at different stage was found to be 268,588 Frws. In this regards, higher post-harvest losses (PHL) of maize have several negative implications for economic losses, which can affect not only individual farmers but also entire communities and nations. In this regards, PHL can have a significant implications for economic losses in the agricultural sector. Post-Harvest Losses refer to the quantitative and qualitative losses of food and agricultural products that occur between the time of harvest and the point of final consumption.

Influence of storage duration of maize on its postharvest losses

The study used multiple linear regressions to determine influence of storage duration of maize on its postharvest losses in Nyagatare district, Rwanda. The econometric findings from MLR model showed that only time store the maize before selling was statistically significant at 1% and 5% level of significance respectively influenced maize post-harvest losses for small scale maize producers in Nyagatare District, Rwanda.

Impacts of methods of postharvest handling and storage on postharvest losses of maize

The study used multiple linear regressions to determine impacts of methods of postharvest handling and storage on postharvest losses of maize in Nyagatare district, Rwanda. The econometric findings from MLR model showed that only materials used in harvesting, transportation after harvesting, mode of transport of produce, equipment used in maize drying, maize Shelling method and materials used in maize storage affected maize post-harvest losses for small scale maize producers in Nyagatare District, Rwanda and were statistically significant at 1%; 5% and 10% level of significance respectively for small holder maize growers in Nyagatare district.

Impact of farmers' skills and knowledge on preventing maize postharvest losses

The study used multiple linear regressions to determine impact of farmers' skills and knowledge on preventing maize postharvest losses. The econometric findings from MLR model showed that only Knowledge on maize quality parameters and Knowledge of poor transportation affected maize post-harvest losses for small scale maize producers in Nyagatare

District, Rwanda and were statistically significant at 5% and 10% level of significance respectively for small holder maize growers in Nyagatare district.

Influence of institutional factors on Post-Harvest economic Losses of Maize

The study used multiple linear regressions to determine the influence of institutional factors on Post-Harvest economic Losses of Maize in Nyagatare district, Rwanda. The econometric findings from MLR model showed that only access to extension services, access to markets information, access to bank credits, trainings on PHHS practices and distance to nearest market affected maize post-harvest losses for small scale maize producers in Nyagatare District, Rwanda and were statistically significant at 5% and 10% level of significance respectively for small holder maize growers in Nyagatare district.

5.2 Conclusion

Based on the above summary of findings, the following conclusion were drawn from the major results.

Estimation of the magnitude and distribution of maize post-harvest losses in Rwanda

The research findings on magnitude and distribution of post-harvest losses by nodes varied from 10.43% to 23.58% respectively. It was found that on average, PHL in Nyagatare district is about 15.98% in the whole maize value chain. In conclusion, addressing maize post-harvest losses in Rwanda is not only a matter of economic significance but also crucial for ensuring food security and improving the livelihoods of smallholder farmers. Efforts should be directed toward investing in infrastructure, technology, and education while fostering collaboration between stakeholders in the agricultural sector. Reducing post-harvest losses is an important step toward enhancing Rwanda's food security and agricultural sustainability.

Estimation of the economic impact of maize post-harvest losses on individual farmers

From this objective, It was found that CAMARU cooperative is the leading one to have highest lost in terms of Revenue with economic loss of 353,966 Frws while the least cooperative to have less economic loss is KOTEBARU with 191,625 Frws while on average the economic losses due to maize Post Harvest Losses at different stage was found to be 268,588 Frws. In conclusion, estimating the economic impact of maize post-harvest losses on individual farmers highlights the urgency of addressing this issue. By reducing these losses through improved practices, technology adoption, and supportive policies, smallholder farmers can enhance their livelihoods, increase their income, and work towards breaking the cycle of poverty. This not only benefits farmers but also contributes to food security and economic development at the community and national levels.

Influence of storage duration of maize on its postharvest losses

The study used the MLR models to determine to determine Influence of storage duration of maize on its postharvest losses in Nyagatare district, Rwanda. The findings from MLR model confirmed that storage duration of maize influenced postharvest economic losses in Nyagatare district, Rwanda. Therefore, the study findings concluded time store the maize before selling affected Post-harvest economic losses for small-scale maize producers in Nyagatare District, Rwanda.

Impacts of methods of postharvest handling and storage on postharvest losses of maize

The study used the MLR models to determine to determine impacts of methods of postharvest handling and storage on postharvest economic losses of maize in Nyagatare district, Rwanda. The findings from MLR model confirmed that methods of postharvest handling and storage affected postharvest economic losses of maize in Nyagatare district, Rwanda. Therefore, the study findings concluded that materials used in harvesting, transportation after harvesting, mode of transport of produce, equipment used in maize drying, maize Shelling method and materials used in maize storage affected postharvest economic losses in Nyagatare District, Rwanda for small scale maize producers.

Impact of farmers' skills and knowledge on preventing maize postharvest losses

The study used the MLR models to determine to determine impact of farmers' skills and knowledge on preventing maize postharvest losses on postharvest economic losses of maize in Nyagatare district, Rwanda. The findings from MLR model confirmed that farmer' skills and knowledge on preventing maize postharvest losses on postharvest losses of maize in Nyagatare district, Rwanda. Therefore, the study findings concluded that Knowledge on maize quality parameters and Knowledge of poor transportation affected maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda for small holder maize growers in Nyagatare district.

Influence of institutional factors on Post-Harvest economic Losses of Maize

The study used the MLR models to determine to determine Influence of institutional factors on Post-Harvest economic Losses of Maize in Nyagatare district, Rwanda. The findings from MLR model confirmed that farmer' skills and knowledge on preventing maize postharvest losses on postharvest losses of maize in Nyagatare district, Rwanda. Therefore, the study findings concluded that access to extension services, access to markets information, access to bank credits, trainings on PHHS practices and distance to nearest market affected maize post-harvest economic losses for small scale maize producers in Nyagatare District, Rwanda for small holder maize growers.

5.3 Recommendations

Broadly, there is a need to sensitize key value chain stakeholders on PHL and their economic implications, and to involve them in the co-creation of strategies that are aimed at minimizing such maize losses.

As revealed by the study findings,

1. That the time maize is stored before selling it was statistically significant at 1% and 5% level of significance respectively (p-value of $0.000<0.001$) to influence maize post-harvest losses, therefore, the researcher recommends that there farmers should be trained on proper time for maize storage and extension services approach that better time storage should be less than 6 months in the warehouse.

2. That materials used during harvesting, mode of transport of produce, equipment used in maize drying, maize Shelling method and materials used in maize storage affected maize post-harvest losses for small scale maize producers in Nyagatare, therefore the researcher recommends government together with its partners to put in place required infrastructures such as feeder roads that enable farmer to smoothly transport their produce either from the farms to households or from the households to the markets. The Government through extension services to build the capacity in terms of training on how to fabricate transportation equipment such as local mechanized tools and the proper use of such machines and other transportation equipment and should be decentralized at farmer level.

   Drying of crops is another operation where mechanized machines are useful. Crop drying is an important post-production food preparation operation that can significantly reduce postharvest losses. Different types of dryers are available for crop drying under small, medium and large-scale operations. The researcher therefore recommends that

MINAGRI should put in place mobile maize dryer because such dryers help to reduce the moisture contents of the harvested crops to the optimal levels before storage.

3. That knowledge on maize quality parameters and Knowledge of poor transportation affected maize post-harvest losses for small scale maize producers in Nyagatare District, and were statistically significant, the researcher therefore recommends that they should be more training on good Post-harvest handling practice (PHHS) like pre harvesting, harvesting, transportation, drying, threshing, winnowing, sorting and grading, as well as storage.

4. That access to extension services, access to markets information, access to bank credits, trainings on PHHS practices and distance to nearest market affected maize post-harvest losses for small scale maize producers in Nyagatare District and were statistically, therefore, most of Post-harvest losses accrued during in transportation and storage operations at farm level and maize storage processes. The researcher therefore suggests that there is a need of joint actions and collaboration between government institutions and stakeholders like climate resilience and Post-harvest handling and Agribusiness support project (PASP) to increase distribution of Post-harvest handling equipment like tarpaulins, tractors, and warehouse management tools to reduce Post-harvest handling losses.

5.3.1 Area for further research

Further researches in the area of post-harvest studies of maize commodities concerning the determinants of maize post-harvest economic losses in Nyagatare District, Rwanda by using multiple linear regression model. The study therefore recommends using the cost benefit analysis (CBA) to indicate the economics of Post-harvest handling and storage practice and their effectiveness on the adopters through Propensity Score Matching. In addition, the study suggested that further research should be undertaken at national level to assess the economic losses from Post-harvest Loss of maize.

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APPENDICES

Appendix 1: Table1. 5: Maize production in Rwanda since 1969-2017

Years	Maize production (tons)	Years	Maize production (tons)
2017	358,417	1989	95,000
2016	374,267	1988	135,000
2015	370,140	1987	90,665
2014	583,096	1986	89,590
2013	667,833	1985	99,452
2012	573,038	1984	101,900
2011	525,679	1983	110,300
2010	432,404	1982	91,956
2009	286,946	1981	84,800
2008	166,853	1980	85,059
2007	101,659	1979	83,348
2006	96,662	1978	75,635
2005	97,251	1977	77,166
2004	88,209	1976	70,627
2003	78,886	1975	67,457
2002	91,686	1974	63,696
2001	80,979	1973	54,755
2000	62,501	1972	49,917
1999	54,912	1971	56,388
1998	58,618	1970	64,062
1997	83,427	1969	41,300
1996	66,595	1968	42,800
1995	56,000	1967	53,200
1994	67,000	1966	48,900
1993	87,000	1965	43,998
1992	98,000	1964	21,311
1991	104,000	1963	7,700
1990	101,000	1962	68,744
		1961	28,434

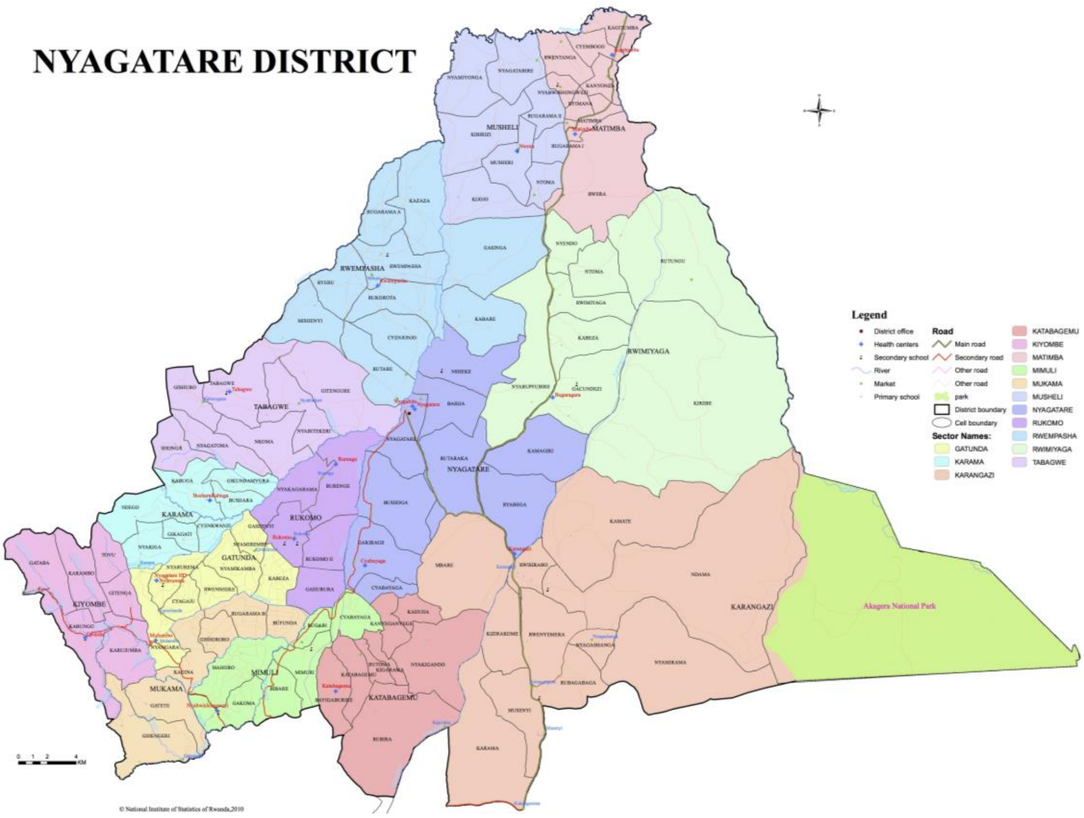
Source: FAOSTAT, 2019

Appendix 2: Table1. 6: Analysis of Postharvest loss estimates – dry weight loss

Year	**Total Production (MT)**	**% Losses**	**Quantity lost (Kg)**	**Price per Kg in Rwf**	**Currency USD in Rwf**	**Price per Kg in USD**	**Value loss in USD**
2006	62,501.00	**18.0**	3,057.00	**130**	**545.2**	**0.22**	**672.54**
2007	102,447.00	17.7	19,283.71	138	548.3	0.25	**4,820.93**
2008	166,852.50	18.0	30,025.28	140	546.1	0.26	**7,806.57**
2009	286,947.40	18.0	51,635.89	155	571.5	0.27	**13,941.69**
2010	432,403.90	18.0	75,600.25	174	592.8	0.29	**21,924.07**
2011	525,679.30	22.5	114,245.31	180	602.8	0.3	**34,273.59**
2012	459,426.60	19.0	108,480.28	181	619.5	0.29	**31,459.28**
Total	**1,973,757**		**402,328**				**114,898.68**

Source: (APHLIS, 2012) cited in (R. Hodges & Maritime, 2012; Kaminski & Christiaensen, 2014a), (NISR, 2014) and (NBR, 2018). [https://www.aphlis.net/en/page/1#/datatables/crops-losses?lang=en&metric=prc&year=2011&country=501]

Appendix 3: Study Area map (Nyagatare Administrative Map)



Source: Nyagatare District website, August 2023

Appendix 4: Sample photo for focus Group Discussion (Rukomo Sector, Nyagatare District)

Source: Photo taken by the researcher, July 2023

Appendix 5: A sample one of the maize warehouses in Nyagatare District, CAMARU Cooperative

Source: Photo taken by the researcher, July 2023

Appendix 6: Survey Questionnaire

Section A: Background information (Bio-Data).

Name ……………………………………

District………………..…………………

Sector………………………………

Cell…………………………………………

Village………………………………………

Please TICK the response most appropriate to

you

Code	**Question (s)**	**Modalities**
1	Gender	(a) Male
		(b) Female
2	Age range	(a) Below 19
		(b) 20 – 29
		(c) 30 – 39
		(d) 40 – 49
		(e) 50 – 59
		(f) 60 and above
3	Level of education	(a) Bachelor
		(b) Diploma
		(c) Secondary
		(d) Primary
		(e) Did not complete primary
		(f) Never got formal education
4	Marital status	(a) single
		(b) married
		(c) Divorced/separated
		(d) Widowed
5	Main occupation	(a) Farmer
		(b) Trader
		(c) Civil servant
		(d) professional worker

Code	Question (s)	Modalities
		(e) house wife
		(f) Student
		(g) Others (specify)
6	What other activity do you engage yourself apart from the one you have mentioned above?	
7	Which language do you understand most?	(a) Kinyarwanda
		(b) French
		(c) Kiswahili
		(d) English
		(e) Others (specify)
Education level	Indicate your level of education	(a) Never attended school
		(b) Primary
		(c) Secondary
		(d) University
		(e) Vocational trainings
Distance to nearest infrastructure	What is your distance from your residence to nearest infrastructure	Distance to nearest road
		Distance to nearest market
		Distance to nearest financial institutions
		Distance to nearest milk collection centre

Part 2

code	Question	Alternative
10	How long have you been growing maize?	(a) the whole of my life
		(b) over 10 years
		(C) 1-10 years
		(d) less than a year
11	What is your average acreage of maize per season?	(a) over 10 hectares
		(b) 5-10 hectares
		(c) 1-4 hectares
		(d) less than a hectare (specify)
12	What variety of maize do you mainly grow?	(a) local unidentified breeds
		(b) local

code	Question	Alternative
		(c)Pannar 53
		(d) others (specify)
13	At what stage do you harvest your maize?	
14	On what materials do you heap your maize during harvesting	(a) tarpaulins
		(b) other materials (specify)
		(d) Bare ground
15	Do you immediately transport your maize for storage on that day of harvest?	(a) yes
		(b) no
		(c) after some days (specify)
		(d) shelled and sold off in garden
		(e) shelled in garden and transported home
16	What mode do you use to transport your harvest for storage?	(a) tractor
		(b) bicycle
		(c) other (specify)
17	Do you realize a quantity reduction in the maize loaded for transportation and that off loaded for storage?	(a) yes Specify
		(i) around 50%
		(ii) 30%-49%
		(iii) 10%-29%
		(iv) 5%-9%
		(v) 1%-4%
		(vi) No (0%)
18	What kind of storage facility do you use to store your harvested maize?	(a) modern maize crib
		(b) locally constructed crib
		(c) local granary
		(d) others (sspecify)
19	What are the causes of post- harvest loss in your storage facility	**Tick multiple options** (a) insects
		(b) rodents
		(c) thieves
		(d) moulding
		(e) others (specify)
20	Identify one major cause of post-harvest loss from the above and rate the qualitative and quantitative loss of maize in storage before shelling.	(Cause)……………………….

code	Question	Alternative
		(a) beyond 50%
		(b) 30%-49%
		(c) 10%-29%
		(d) 5%-9%
		(e) 1%-4%
		(f) 0%
21	How do you dry your maize	(a) sun heat (maize spread on tarpaulin)
		(b) sun heat (maize spread on bare ground)
		(c) sun heat (maize spread on roof top)
		(d) others (specify)
22	How can you rate the percentage of maize grain lost during drying?	(a) beyond 50%
		(b) 30%-49%
		(c) 10%-29%
		(d) 5%-9%
		(e) 1%-4%
		(f) 0%
23	What method do you use in shelling your maize?	(a) maize Sheller
		(b) beating with sticks
		(c) hand shelling
		(d) others (specify)
24	What materials do you use to ensure cleanliness and reduced scattering of maize during shelling?	(a) tarpaulin
		(b) bare ground
		(c) other material (specify)
25	How can you rate the percentage of maize grain lost during shelling?	(a) beyond 50%
		(b) 30%-49%
		(c) 10%-29%
		(d) 5%-9%
		(e) 1%-4%
		(f) 0%
26	What materials do you use For packaging your maize grains after shelling?	(a) traditional gunny bag
		(b) hermetic storage (specify)

code	Question	Alternative
		(c) plastic silo
		(d) super grain bag (multi-layer polyethylene storage bag)
		(e) metallic silo
		(f) others (specify)
27	Do you have a special facility for storing your packaged maize?	(a) yes
		(b) no (specify where you store)
28	If yes, and you use traditional gunny bags or super grain bags, what do you use to control ground moisture uptake by maize?	(a) pallets
		(b) logs
		(c) stones
		(d) others (specify)
29	What method do you use to keep away pest from your storage facility?	(a) fumigants
		(b) others (specify)
30	For what period do you store your maize before selling it off?	(specify)
31	Where/how do you market your maize?	(a) traders find me on my farm
		(b) I take it to buyers at their stores
		(c) others (specify)
32	How many kgs of maize did you sell off in your last harvest?	(specify)
33	How much did you sell each kg?	(specify)
34	Do you know any maize grain quality parameter specifications from any organization?	(a) yes (specify) (b) No
35	Have you accessed credits	a) Yes b) No
36	Have you ever trained on:	Trainings on Good Agriculture Practices (GAP)
		Trainings on pest and diseases control
		Trainings on Farm records
		Trainings on PHHS practices
		Trainings on Quality and safety
		Trainings on sorting and Grading