

BINDURA UNIVERSITY OF SCIENCE EDUCATION

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DEPARTMENT OF AGRICULTURAL ECONOMICS AND MANAGEMENT



**AN ASSESSMENT OF POST-HARVEST LOSS IN MAIZE VALUE CHAIN IN WARD 5
(CHINGWERE), MHONDORO-NGEZI DISTRICT IN MASHONALAND WEST
PROVINCE**

BY

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DECLARATION

I, Mawoko Ishmael (Registration Number: B224734B), hereby declare that this dissertation entitled "Assessment of post-harvest loss in maize value chain in Ward 5 (Chingwere), Mhondoro-Ngezi District in Mashonaland West Province" is my original work. This research has not been submitted for any degree or examination at any other university, and all the sources I have used or quoted have been acknowledged and referenced completely.

Student's Signature:



Date:

24 / 06 / 2026

This dissertation has been approved for submission with my permission as the supervisor.

Supervisor's Signature:



DEDICATION

This dissertation is joyfully dedicated to my wonderful mother, R. Sawunyama, whose endless love and sacrifices have been my greatest motivation, and to my awesome little brother, Tanatswa Mawoko, who brings so much light and laughter into my life.

This one is for us!

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A very special and highly respectful appreciation goes to my beloved aunts Mama Chary, Mama Julie, and Mama Rejoe! Your wisdom, prayers, and unwavering support have meant the world to me. I am so blessed to have such phenomenal women in my corner. Thank you for cheering me on! I also want to express my sincere appreciation to my supervisor, Dr V.T Munyati, for their invaluable guidance and patience.

To the smallholder farmers of Ward 5 (Chingwere), Mhondoro-Ngezi District thank you for warmly welcoming me and sharing your stories. This research is for you.

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ABSTRACT

Maize is the cornerstone of food security in Zimbabwe, supplying 60 to 65% of caloric intake for average households. However, smallholder farmers, who produce 70 to 80% of national output, consistently suffer substantial post-harvest losses (PHL) that undermine labour investment, food availability, and income stability, yet ward-specific, empirically quantified data to inform context-appropriate interventions remain scarce. This study assessed the extent, causes, and impacts of PHL in the maize value chain among smallholder farmers in Ward 5 (Chingwere), Mhondoro-Ngezi District. Employing a mixed-methods case study design, the research administered a structured household survey to 128 farmers, conducted 15 key informant interviews, and performed grain quality assessments on a sub-sample of 40 households. Guided by the Sustainable Livelihoods Framework and Diffusion of Innovations Theory, quantitative data were analysed using descriptive and inferential statistics while qualitative data underwent thematic analysis. Total PHL averaged 35% of harvested grain, with storage the greatest hotspot (19%), followed by drying (6%) and shelling (4%). Traditional granaries (dura) caused 23% storage losses, whereas hermetic bags reduced losses to 5%. The average household lost 567 kg of maize per season (USD 160 to 199), translating to ward-level annual losses of USD 58,720 to USD 73,033. Only 19% of households achieved Grade A quality, with Grade C grain suffering 47% price discounts, and 33% of sampled grain had aflatoxin contamination exceeding safe limits, significantly associated with bare-ground drying. High-loss households were food self-sufficient for only 5 months compared to 9 months for low-loss households, confirming a self-perpetuating poverty trap ($r = -0.62$, $p < 0.001$). The primary barriers to adopting hermetic technologies were upfront cost (82%), limited local availability (65%), and lack of knowledge (59%). The study concludes that PHL in Ward 5 is unacceptably high and urgently requires intervention, particularly in storage and drying. Recommendations include a subsidised hermetic bag distribution programme, gender-sensitive post-harvest extension, investment in community drying infrastructure, and improved market incentives for grain quality. Reducing PHL from 35% to 20% would extend household food self-sufficiency by approximately two months, an economic and humanitarian imperative.

LIST OF ABBREVIATIONS

AGRITEX: _____ Department of Agricultural, Technical and Extension Services

APHLIS: _____ African Postharvest Losses Information System

CAADP: _____ Comprehensive Africa Agriculture Development Programme

CI: _____ Confidence Interval

DFID: _____ Department for International Development

FAO: _____ Food and Agriculture Organization

GMB: _____ Grain Marketing Board

IFAD: _____ International Fund for Agricultural Development

LGB: _____ Larger Grain Borer

NGO: _____ Non-Governmental Organization

PHL: _____ Post-Harvest Losses

ppb: _____ Parts per Billion

SLF: _____ Sustainable Livelihoods Framework

USAID: _____ United States Agency for International Development

USD: _____ United States Dollar

ZimStat: _____ Zimbabwe National Statistics Agency

ZimVAC: _____ Zimbabwe Vulnerability Assessment Committee

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Maize, *Zea mays*, is a cornerstone of the Zimbabwean cultural identity, livelihoods in the rural areas and national food security, providing 60–65% of the calories consumed in the homes, and covering approximately 1.5 million hectares each year (ZimVAC, 2024; Ministry of Lands, Agriculture, Fisheries, Water and Rural Development, 2023). However, post harvest losses (PHL) jeopardize the chain from the farm to the plate and this is best understood by stepping down from the continental and global to the local context of ward 5 in Chingwere.

The food loss and waste (FLW) phenomenon is a serious global challenge as 1.3 billion tonnes of food, equivalent to nearly one-third of the total food produced for human consumption, is lost or wasted every year, with a global impact on the economy of nearly USD 936 billion annually and a corresponding need for nearly 250 km³ of water and 1.4 billion hectares of arable land (FAO, 2022; World Bank, 2023; Gustavsson et al., 2021). For cereals, the global average is 10–15%, but in wealthier countries, losses are controlled with cold chain infrastructure at 4–6%, and in Sub-Saharan Africa, losses are 15–25% with some countries reporting losses of more than 30% (FAO, 2022; Affognon et al., 2015; APHLIS, 2023). The UN's SDG 12.3 aims to halve food waste by 2030 (UN, 2020) and the World Bank (2021) estimates that even a 1% reduction on food losses and waste in Sub Saharan Africa could recover USD 40 million per annum.

Mashonaland West Province is Zimbabwe's top maize-producing province, accounting for 30–35% of the country's maize production (ZimStat, 2024). The total number of smallholder households in the Ward 5 (Chingwere) of Mhondoro Ngezi District is around 350 to 400 households with an average of 1.2 to 1.8 hectares per household of maize grown under rain-fed condition with an average yield of 2.2 to 3.5 tonnes per hectare, which is marginally higher than the provincial average (AGRITEX Mhondoro Ngezi, 2024). However, in similar neighbouring wards, the proportion of post harvest losses is estimated at 20–35%. Whereas assessed losses of 25% of the harvest for each hectare mean that a Grain Millers Association household loses USD 100 to 150 of invested resources per hectare (Grain Millers Association of Zimbabwe, 2024). This study is focused on Ward 5 as a way of providing the granular, context specific evidence that currently is missing from the policy discussions and intervention design.

1.2 Statement of the Problem

Maize is the main staple crop and source of income for smallholder farmers in Ward 5 (Chingwere), and ideally most of the harvested grain should be retained for household consumption and marketed to generate income. However, significant post-harvest losses continue to occur at different stages of the post-harvest chain, particularly during storage, drying, shelling, transportation, and marketing. These losses reduce the quantity and quality of maize available for food and sale, thereby undermining household food security, labour productivity, and income generation. Evidence suggests that some households lose between 23% and 46% of their harvest, resulting in substantial reductions in marketable surplus and foregone income. Although post-harvest losses are recognized as a national challenge, there is limited empirical evidence on the magnitude, causes, and specific loss hotspots in Ward 5. Furthermore, existing estimates are largely based on provincial or national averages and do not reflect household-level experiences, while farmers' perceptions of the feasibility and affordability of post-harvest management technologies remain poorly understood. Consequently, the extent and drivers of maize post-harvest losses in Chingwere Ward remain insufficiently documented, making it difficult to design targeted and effective interventions to reduce losses and improve food security and livelihoods. Therefore, this study seeks to quantify the magnitude of maize post-harvest losses at household level, identify the critical loss hotspots along the post-harvest chain, examine farmers' experiences and perceptions regarding existing post-harvest management practices, and generate evidence-based recommendations that can support the development of appropriate and context-specific interventions for reducing losses and improving household food security and income in Ward 5 (Chingwere).

1.3 Objectives of the Study

1.3.1 Main Objective

To evaluate the magnitude, the causes and effects of the post-harvest losses in the maize value chain to smallholder farmers in Ward 5 (Chingwere) of Mashonaland West Province.

1.3.2 Specific Objectives

To identify the key actors and their roles in maize value chain in Chingwere ward.

To determine causes and hotspots of post harvest losses in the maize value chain in the ward.

To quantify the economic and qualitative losses caused by post harvest losses.

To assess current strategies and make recommendations for action on how to minimize post harvest losses in Chingwere Ward.

1.4 Research Questions

This study is guided by the following research questions:

Who the key players are and what their roles are in the maize value chain in Chingwere Ward?

What are the key challenges and hotspots of post harvest losses in the maize value chain in the ward?

What are the impacts of these losses on smallholder farmers in terms of economics and quality in Chingwere?

How can post harvest losses be minimised in the maize value chain in Chingwere Ward?

1.5 Significance of the Study

The results of this research are likely to be very useful to a number of stakeholders who will all directly benefit from the evidence and recommendations produced. This study aims at documenting the post harvest challenges faced by the smallholder farmers and the loss hotspots and most cost effective mitigation measures in the context of the smallholder farmers in Chingwere, with the view of contributing directly to the food availability and household income.

The research delivers ward-level evidence-based data to support specific training, allocation of resources and policy development for the reduction of PHL for local policy makers and AGRITEX, to equip extension agents with specific data to change from generic to problem-specific advice.

The study provides a realistic, context-sensitive evaluation of the situation in Mhondoro Ngezi District to shape better action over post-harvest constraints for farmers, which the study participants, including development agencies such as CARE International, World Vision, and Zim Aid, have found essential.

From an academic perspective, this study provides a detailed case study of the situation in a ward thus supplementing the existing knowledge literature on post-harvest management in Zimbabwe and on value chain specific, locally embedded loss estimation that accounts for smallholder heterogeneity beyond national aggregates.

The study also shows how the goals of the African Union CAADP and its Kampala Declaration (2025) on post harvest loss reduction can be translated into local, measurable action in the context of national and regional goals.

1.6 Scope and Limitations

1.6.1 Scope

The area of interest is limited to Ward 5 (Chingwere), Mhondoro Ngezi District with specific thematic emphasis on the maize value chain, that is, from production to post harvest handling, storage and marketing. The study focuses on smallholder farmers as the main producers and victims of PHL, alongside other actors (traders, transporters, and millers) without making them the focus of the analysis, but includes losses from harvest to sale or household consumption.

1.6.2 Limitations

There are some caveats. This study is based on the self-reported harvest and loss data, and the farmers are usually convinced that they have harvested the crops in buckets, tins and bags with their approximate estimates, which introduces some level of error in the conversion of the harvest and loss data from buckets, tins and bags to Kilogram. The findings are part of the agro-ecological, socio-economic and infrastructural context of Chingwere Ward; therefore, there is a need for caution in generalising where it is not applicable, but replicable elsewhere. The study takes place over one agricultural season and losses are subject to annual fluctuations as a result of changing climate, pest populations and prices, which would have required a multi-season

study, but was not feasible. Lastly, some of the sampled households were unable to use moisture meters and weighing scales due to resource constraints.

1.7 Dissertation Outline

This dissertation has been composed in five chapters. Chapter 1 has presented the background, problem statement, research questions, research objectives, level of significance, scope and limitation of the study. The second chapter provides a review of the existing literature on post-harvest losses and the theoretical and conceptual basis for the research undertaken, while also highlighting areas for further study. Chapter three outlines the research methodology, namely, the research area, the research design, sampling and data collection methods, and ethical considerations. The findings and results of the study are presented in Chapter 4. The chapter 5 presents conclusions and recommendations of the study.

1.8 Chapter Summary

The chapter introduced the study by tracing the global, continental, national and local context of maize PHL, the problem with detailed quantification of harvests, stage-wise losses and reduction in surpluses, object of the study, problem of the study, significance of the study to farmers, policymakers, extension services, NGOs and academia and scope and limitations. The next chapter is a review of existing literature on PHL, and value chain analysis in the Zimbabwean smallholder context.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A literature review of existing literature on PHL in the maize value chain, specifically in the context of smallholder systems in Sub Saharan Africa and Zimbabwe is undertaken. Section 2.2 introduces key terms, Section 2.3 introduces the theoretical framework, Section 2.4 introduces the conceptual framework, Section 2.5 reviews empirical literature by objective, Section 2.6 aggregates research gaps and Section 2.7 summarises this chapter.

2.2 Definition of Key Terms

2.2.1 Post Harvest Losses (PHL)

There are different definitions of post-harvest loss in the literature. Others researchers have concentrated on the physical and qualitative deterioration of food from harvesting to eating, not including pre-harvest or retail losses (FAO, 2019; Hodges et al., 2011); others on the economic and nutritional losses as food moves from the farm to the consumer (World Bank, 2022), and still others viewing PHL as losses from threshing to market, either from the effects of spillage, pests or contamination (Affognon et al., 2015; Kumar & Kalita, 2017). In Zimbabwe these losses are very localized and influenced by the technologies, information and markets available to farmers (Mvumi et al., 2022). This study draws on the understanding that losses occur during the post-harvest phase and are experienced by the smallholders in Ward 5 in Chingwere, which is both spatially and sequentially defined; can be measured and experienced with regard to both quantity and quality losses of maize grain; covers the entire post harvest value chain of maize grain from harvesting until sold or consumed within the household.

2.2.2 Maize Value Chain

The value chain is generally seen as a chain of activities that pass a product from its conception to its production, delivery and eventual disposal (Kaplinsky & Morris, 2001), in agriculture, a chain from the farm to the end destination (Hellin & Meijer, 2006), and in institutional and coordination terms, a chain of institutions and coordination mechanisms (Webber & Labaste, 2010) or a “farm-to-fork” continuum (FAO, 2021). Maize value chain in Zimbabwe connects the smallholder to the input provider, trader and millers (Ministry of Lands, Agriculture, Fisheries,

Water and Rural Development, 2023). For this study it refers to the web of actors and value adding transformations which take maize from harvest to post harvest handling, storage and marketing to the farmer's destination, with a particular focus on the post harvest component, recognising the linkages which influence farmer behaviour in Ward 5.

2.2.3 Smallholder Farmers

Smallholders are usually defined in terms of land size, assets and livelihood strategies, such as farmers with less than two hectares of land and limited access to inputs, credit and markets (IFAD, 2020); households with few assets and operate in a high-risk environment where they have limited information and access to technology (World Bank, 2021). Yet, economic definitions are too narrow to reflect the realities of Zimbabwean smallholder life where communal and resettled farmers combine subsistence agriculture with market-oriented selling and other sources of income including remittances and non-farm income (Cousins, 2010; Scoones et al., 2019). ZimVAC (2024) deems them operationally as households operating agriculture on land less than 5ha, mainly rain-fed, with minimum irrigation, little or no machinery and no formal finance. This study uses a localised definition: households growing 0.5 – 3.0 hectares of rain-fed maize crops, using improved and retained seed, relying on family labour, and who sell maize surplus through formal (GMB) or informal markets, that reflect the heterogeneity of the maize farmers in Ward 5.

2.2.4 Food Security

The World Food Summit (WFS) 1996 basic definition of food security is based on 4 pillars: availability, access, utilisation and stability, which translates to the consistent physical, social and financial access to adequate, safe, nutritious food. USAID (2020) translates this into dietary diversity, frequency and food expenditure, while in Zimbabwe it is considered as the ability of the living unit to provide the dietary requirements of its members throughout the year by harvesting or purchasing food or through support (ZimVAC, 2024). By contrast, food security is conceptualized in Sen (1981) as an entitlement, legal control over food through production, trade and transfers. In this study, the concept of food security for smallholder maize farmers is defined as meeting the annual maize needs through their own production (or purchase/transfers) without

experiencing food hunger or difficulty in selling assets during the lean season and considering post harvest losses as a direct threat to food security.

2.2.5 Hermetic Storage

Hermetic storage is an airtight, low oxygen environment which, due to insect respiration and carbon dioxide production in the grain, prevents pest reproduction and mould growth, avoiding the use of chemical insecticides (Tefera et al., 2021; Kumar and Kalita, 2017; Mvumi et al., 2022). Smallholders have strong protection from infestation or elimination of infestation and good grain moisture retention as a result of these technologies including metal silos, hermetic bags and plastic drums that protect the grain from pests including the Larger Grain Borer and maize weevil for up to one year (APHLIS, 2023; World Bank, 2022). In this research, hermetic storage is interpreted as closed containers or bags which exclude oxygen from entering and insects infesting the stored grain, thereby preserving the quality and quantity of grain, and is recognized as a possible intervention for loss reduction in Ward 5.

2.2.6 Grain Quality

Grain quality is a multidimensional aspect that includes the physical, chemical, nutritional and sanitary characteristics that are used to assess their acceptability and market value (FAO, 2022). In the commercial market, quality maize is clean, dry, uniformly coloured, pest-free, mould-free, and has a test weight of more than 72kg/hl (Grain Millers Association of Zimbabwe, 2024), while in the smallholder market, high-quality maize has less than 13.5% moisture and Grade A or B (Mvumi et al., 2022). One of the key food-safety aspects is freedom from aflatoxins at or below the legal limit; 10 ppb total and 5 ppb is the limit for aflatoxin B1 (Stathers et al., 2020) as reduced quality reduces visual appeal, nutritional value and market price (Hodges et al., 2021). This study uses the physical soundness, dryness, purity and market acceptability of maize as a measure of grain quality, operationalising the loss of quality as a price discount for sub-standard grain, determined by insect damage, broken grain, foreign matter, and moisture content.

2.3 Theoretical Framework

The Sustainable Livelihoods Framework is used to explain the vulnerability context that is influencing post-harvest losses, while the Diffusion of Innovations Theory explains why some farmers adopt new technologies, and others do not. Two complementary theories were selected

for this study: the Sustainable Livelihoods Framework is used to explain the vulnerability context that is influencing post-harvest losses; the Diffusion of Innovations Theory explains why some farmers adopt new technologies, and others do not.

2.3.1 Sustainable Livelihoods Framework

DFID (1999) has developed a sustainable livelihoods framework (SLF) which is a tool for understanding the strategy and outcome of rural households. It suggests that households possess five types of capital: human, social, natural, physical and financial, which interact with the vulnerability context (shocks, seasonality, trends) and the transforming structures and processes (institutions, policies, power relations) to yield livelihood strategies and outcomes (DFID, 1999; Scoones, 2009; Chambers & Conway, 1992).

The SLF is important in this context in several ways. The framework conceptualises post harvest losses as a shock that reduces the financial capital, food capital and human capital (lost labour), needed for improved post harvest practices, and the constraints, including lack of financial capital for hermetic bags, limited knowledge of drying and storage practices, and inadequate storage structures, that prevent the adoption of improved practices are interconnected; it situates household decisions within institutions like AGRITEX and the Grain Marketing Board; and it emphasises livelihood outcomes beyond income, such as food security and well-being, that are each directly affected by PHL, as argued by Scoones (2009) and Bebbington (1999).

2.3.2 Diffusion of Innovations Theory

Developed by Rogers (1962, 2003), the Diffusion of Innovations Theory is an explanation of the way in which new ideas and technologies enter a social system through certain channels over a period of time. It recognizes five factors that affect the adoption process: relative advantage, compatibility, complexity, trialability, and observability. This theory explains why some Ward 5 farmers have not or have adopted the hermetic storage or improved drying or mechanical shellers. Although hermetic bags are perceived as having a clear relative advantage over traditional granaries, barriers to adoption include perceived complexity, cost, and limited trialability (Mvumi et al., 2022; Tefera et al., 2021). The theory also emphasizes the importance of opinion leaders in diffusion; therefore extension efforts should focus on those farmers who can show the innovations to others (Rogers, 2003; Valente & Davis, 1999).

2.4 Conceptual Framework

The conceptual framework of this study as shown in Figure 2.1 hypothesized the relationship between independent variables, intervening variables and dependent variables. The framework brings together the theoretical views mentioned above and empirical literature featured in the following sections.

2.1: Conceptual Framework for Post Harvest Losses in the Maize Value Chain, Ward 5, Chingwere

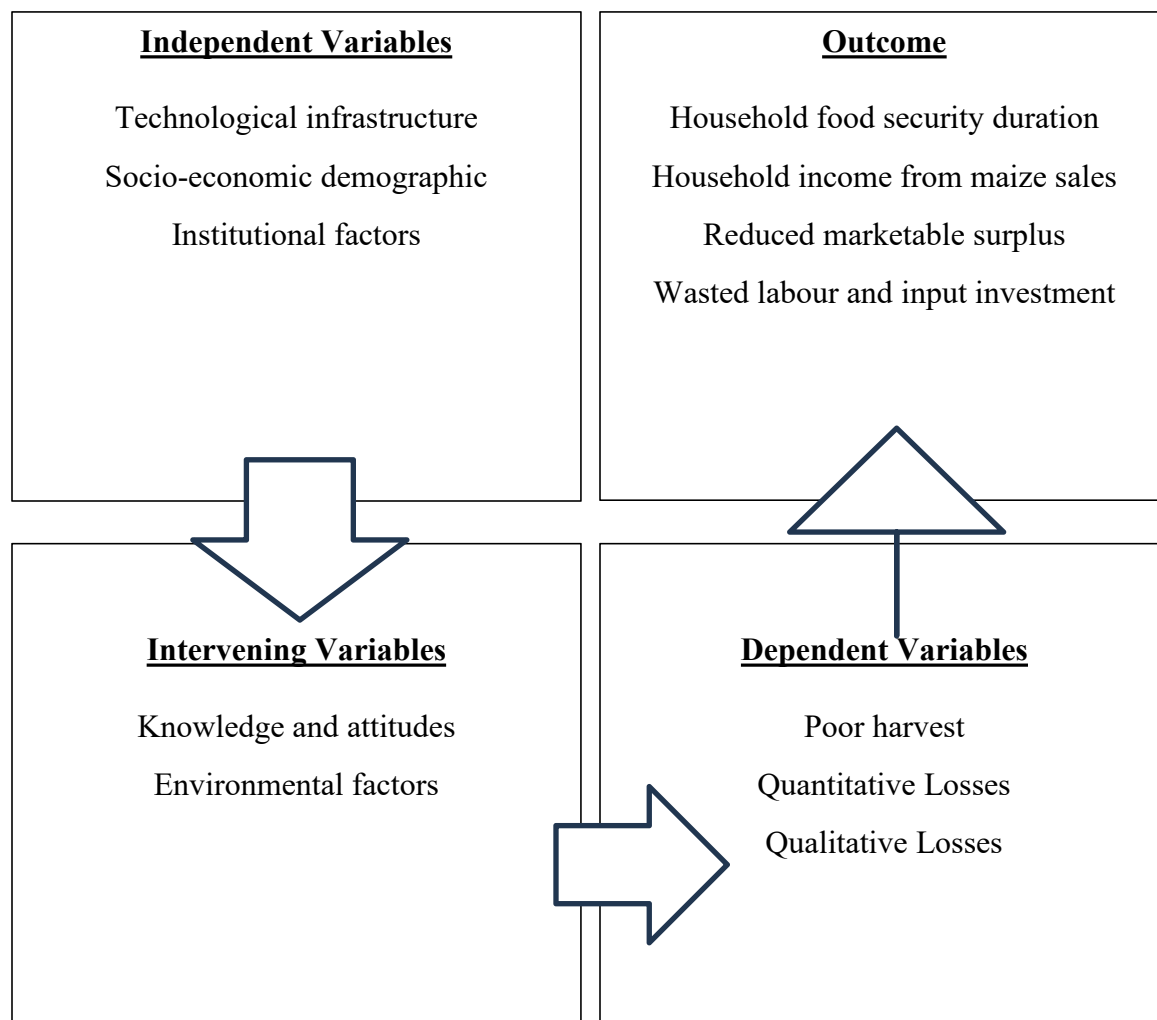


Figure 2.1 Conceptual Framework for Post-Harvest Losses in the Maize Value Chain, Ward 5, Chingwere

The dependent variable is post-harvest losses which is operationalised in quantitative terms (percentage and total grain loss, economic value) and qualitative terms (insect damage, broken

grain, mould, moisture content, price discount) under harvesting, drying, shelling, storage and transport/marketing.

Independent variables are divided into three categories. The type of storage structure is hypothesised as the most important factor influencing losses (hermetic storing below 10% versus 15-25% for traditional storing), the drying method influences the moisture content and mould risk, and the shelling method impacts the broken grain rate, storage susceptibility, and the price of the grain.

Farmers' ability to invest in improved technologies is influenced by socio-economic and demographic factors: farmers' education level affects their ability to adopt improved technologies, and knowledge about moisture content, household size/labour availability, off-farm income and group membership affects the timeliness of operation.

Information, technology and markets are being mediated by the institutional factors. The frequency of extension contacts is thought to be negatively related to losses, distance to market is thought to affect when and how much is sold and transport losses, and the availability of credit is thought to facilitate investments in storage technologies.

Farmers' knowledge of the recommended practices, attitudes toward loss reduction (perceived importance, self-efficacy), and environmental factors, such as the rainfall during harvesting and drying, are intervening variables, with exogenous variation in mould risk due to rainfall.

The consequences of post harvest losses include household food insecurity, loss of income and loss of labour and financial investment, which ultimately affects asset levels of the household creating a poverty trap where losses lower the ability of the household to invest in loss reduction technologies.

2.5 Empirical Literature Review

2.5.1 Empirical review of key actors and their roles in the Maize Value Chain.

Maize is a subject of intensive study in the value chain in Sub-Saharan Africa because it plays an important role in food security, livelihoods and agricultural development (Poulton et al., 2010; FAO, 2022). Poulton et al (2010) identified several key actors within the maize value chain:

input suppliers, maize producers, rural assemblers, transporters, large-scale traders, processors and retailers. Input suppliers are key in supplying seeds, fertilizers, agrochemicals and other production inputs required for maize production (FAO, 2022). Maize is produced and harvested by a majority of smallholder farmers, and the rural assemblers gather grain from smallholder farmers across a large area and connect them to the larger markets (Poulton et al., 2010). While rural assemblers play a key role in providing market access for smallholder farmers, the study also noted that they are often operating in challenging environments where infrastructure is poor, capital is limited and quality control is weak (Poulton et al., 2010). Milling, packaging, and distribution activities by processors and retailers add value to maize, bringing maize products to consumers in various formats and market segments (World Bank, 2021).

The maize marketing system in Zimbabwe comprises of both formal and informal value chain arrangements, with different types of actors working through different institutional arrangements (Jayne et al., 2010; Mutami, 2015). Jayne et al. (2010) found that the Grain Marketing Board (GMB) and large milling companies are dominant in formal channels and in informal channels the farm-gate buyers, village traders and local assemblers and cross-border traders are the dominant channels. These informal markets are not only important for maize sales by smallholders, but they also make up a large share of this market for smallholder maize sales in surplus-producing provinces like Mashonaland West (Jayne et al., 2010). Farmers have quick access to cash and more flexible market opportunities through informal channels, but these channels are known to have poor quality grading systems, inconsistent pricing, and poor market transparency (Jayne et al., 2010; Mutami, 2015). This means that smallholders are often lacking in information about market prices, and they can often earn less for their crops (World Bank, 2021).

The organisation of Zimbabwe's maize value chain changed significantly since the implementation of the Fast Track Land Reform Programme with greater involvement of smallholder farmers in maize farming (Rukuni et al., 2018). Despite the emergence of smallholder farmers as dominant producers in several regions of the country, Rukuni et al. (2018) concluded that the bargaining power of these smallholder farmers in the value chain was not very strong. It was said that this situation was brought about by the fragmented production, lack of market information, limited storage facilities and reliance on the intermediaries for market access

(Rukuni et al., 2018). Moreover, the study brought to light the potential role of farmer organisations and cooperatives in strengthening collective bargaining, access to markets and price negotiations for smallholder producers (Rukuni et al., 2018). Findings from other parts of southern Africa indicate that farmer associations have been found to enhance farmers' value chain involvement and share of value chain returns (AGRA, 2021).

On a regional level, Mazvimavi (2021) explored the maize value chain in Mashonaland West and found a variety of actors that deal with maize in transit from production to final markets. The study reveals that the farmers received extension services and technical assistance from AGRITEX while input suppliers were responsible for the availability of inputs including seed and fertilizers, crop protection products (Mazvimavi, 2021). The primary actors in production were the smallholder farmers and the villagers' basic activities in post production included drying and shelling were done by smallholder farmers, while the aggregation and transportation were done by village traders (Mazvimavi, 2021). The Grain Marketing Board (GMB) was a significant buyer as it guaranteed farmers a price, but late payment meant that farmers were not necessarily encouraged to engage in formal markets (Mazvimavi, 2021). Additionally, the study found several coordination problems between value chain actors, such as lack of quality standards, information sharing and payment structures, lowering the value chain's overall efficiency (Mazvimavi, 2021). Similar forms of coordination failures have been documented in other maize value chains in Africa, where the lack of linkages among actors reduce competitiveness and value addition (FAO, 2022).

Gender dynamics also influence the distribution of roles and responsibilities within maize value chains across Africa (Gitau et al., 2020; Doss, 2018). Gitau et al. (2020) found that men are generally more involved in marketing, transportation, and commercial trading activities, while women play a dominant role in post-harvest handling, processing, storage, and household-level grain management. Women often possess extensive knowledge regarding grain preservation, drying practices, and storage management, making them critical stakeholders in efforts to reduce post-harvest losses (Gitau et al., 2020). However, they frequently face constraints such as limited access to productive resources, credit facilities, extension services, and decision-making opportunities within agricultural markets (Doss, 2018). Consequently, interventions aimed at improving maize value chain performance and reducing post-harvest losses are more likely to

succeed when they incorporate gender-sensitive approaches that recognise the distinct roles, knowledge, and challenges faced by both men and women (FAO, 2022; Gitau et al., 2020).

2.5.2 Empirical Review of Causes and Hotspots of Post Harvest losses.

In Sub-Saharan Africa there is a large amount of empirical literature about causes and hotspots of post harvest losses (PHL) in maize value chains, with storage identified as the most critical stage where losses do occur (Affognon et al., 2015; FAO, 2022). Affognon et al. (2015) in a meta-analysis of 67 studies in the region determined that about 60–70% of the total post-harvest losses of smallholder farmers were due to storage. The study noted that the losses were mainly due to insect pests, including the Larger Grain Borer (*Prostephanus truncatus*) and the maize weevil (*Sitophilus zeamais*), as well as poorly constructed storage structures which do not provide protection from penetration by pests and moisture (Affognon et al., 2015). The second hotspot identified was drying, accounting for 2% to 10% of total losses, which is attributed to some issues such as inadequate drying infrastructure, unpredictable weather conditions and poor handling of grain (Affognon et al., 2015). The results indicate that the interventions that focus on the storage and drying phase have the highest potential to reduce the overall post harvest losses in maize producing communities (FAO, 2022).

In addition to the current physical reasons for the loss of grains, researchers have highlighted the importance of developing an understanding of the range of factors that affect post harvest management practices (Hodges et al., 2011). Hodges et al. (2011) distinguished between the direct causes of post-harvest losses such as damage by insects, excessive moisture, fungal contamination, and mechanical damage and the underlying causes of such losses such as low technical knowledge, poor financial resources, poor market systems and constraints imposed by policies. They have concluded that to be effective, loss reduction strategies should not only benefit the direct losses but the underlying drivers of losses as well (Hodges et al., 2011). The authors also reported that although farmers may be more aware of the risk of grain being lost during storage, many still store grain for a long time, either because they are hoping to get better prices later in the season, because they need grain for household consumption, or because they are unable to access reliable markets in time (Hodges et al., 2011). This indicates that when designing post harvest interventions, farmers' economic and livelihood realities must be considered (World Bank, 2022).

Traditional and improved grain storage facilities have been extensively studied for the potential to minimize grain losses, and many studies have shown differences in the performance between the two types of storage (Tefera et al., 2021; Hodges et al., 2011). Traditional granaries were found to have average losses of about 18.4% after 6 months of storage in the controlled trials conducted in Zimbabwe and Kenya, with losses starting to be significant beyond 4 months due to pest build-up (Hodges et al., 2011). On the other hand, hermetic storage technologies like Purdue Improved Crop Storage (PICS) bags and GrainPro bags consistently kept losses under 1% during the same storage duration, which were associated with the creation of barrier conditions that kept insect activity at low levels (Tefera et al., 2021; Hodges et al., 2011). Similarly, metal silos yielded good results, but they were sometimes more expensive to purchase and install (Tefera et al., 2021). Nevertheless, despite the use of different storage technologies, it was also discovered that high grain moisture content was a significant risk factor regardless of technology used, and that moisture content levels exceeding 13.5% promoted mould growth and grain deterioration within a few weeks of storage (Hodges et al., 2011; FAO, 2022). It indicates that good storage management should be coupled with good drying procedures prior to putting grain into storage facilities.

Additionally, farmer knowledge and awareness have been identified as important determinants of outcomes of post harvest losses (Stathers et al., 2020). Stathers et al. (2020) conducted a study and distributed questionnaires to 1200 farmers in various African countries, finding that only 34% had the required knowledge of the recommended post harvest management practices. There was still a great deal that was unknown about safe grain moisture percentages, drying times and identification of major grain storage pests like Larger Grain Borer (Stathers et al., 2020). In particular, only 28% had the correct understanding of the moisture requirements for safe storage, 31% had adequate knowledge of drying requirements, and 42% were able to correctly identify the main storage pests (Stathers et al., 2020). Importantly, the study has shown that a 10% increase in farmer's knowledge scores was linked to a 4.2% decrease in storage losses, demonstrating the importance of farmer education and extension services to reduce storage losses (Stathers et al., 2020).

The importance of post harvest losses in maize storage as the main challenge facing smallholder farmers is also indicated by evidence from Zimbabwe (Mvumi et al., 2022). Mvumi et al. (2022)

found average losses of 18.7% for six months storage and losses were > 30% after 8 months or more storage in one of the most assessments that have been conducted in the country. The study revealed that, about 78% of storage structures surveyed were infested with Larger Grain Borer, causing average losses of 11.3% of stored grain (Mvumi et al., 2022). Apart from losses due to storage, the following loss hotspots were identified: drying, shelling and transportation, which together recorded an average loss of 5.2%, 3.8% and 2.1% respectively (Mvumi et al., 2022). Moreover, 62% of the farmers surveyed said storage was the most critical post production problem so far and of the farmers, only 12% used hermetic storage technologies (Mvumi et al., 2022). The results suggest there is a significant gap between what is available and being used as effective technologies by farming households.

The level of market access has also been found to affect the size of the post-harvest losses suffered by smallholder farmers (Kaminski & Christiaensen, 2014). Kaminski and Christiaensen (2014) conducted a study and reported that farmers who were more than 10 kilometres away from the markets tended to experience higher post-harvest losses than farmers who were better market connected. The authors explained this relationship by pointing out the length of storage periods, the lack of transportation choices and the lack of market price information in remote areas (Kaminski & Christiaensen, 2014). If farmers cannot get their grain off quickly, they may be forced to hold on to the grain for longer, which would bring the additional challenge of pest infestation, quality loss and physical losses (World Bank, 2022). Inadequate infrastructure and poor market linkages can thus have a secondary impact on post-harvest losses, due to the length of time grain is exposed to risk in the household storage system (Kaminski & Christiaensen, 2014)..

2.5.3 Empirical Review of Economic and Qualitative Losses

Post-harvest losses (PHL) have important economic impacts on smallholder farmers, not just a reduction in the physical quantity of grain available for consumption or sale (World Bank, 2022; Affognon et al., 2015). Economic losses are experienced by farmers when losses of grain during harvesting, drying, storage, transport and marketing makes a significant cut to the farm income and returns on investment in the agricultural enterprise (Affognon et al., 2015). The World Bank (2022) estimates the annual post harvest losses in Zimbabwe to be valued at between USD 60 million to USD 200 million which translates to about 1 – 2% of the total agricultural gross

domestic product of the country. Maize losses are disproportionately affecting smallholder farmers, who are typically resource constrained and rely heavily on maize for food security and income generation (World Bank, 2022). The impacts of post-harvest losses on agricultural productivity and rural economic development, therefore, negatively impact the overall contribution of the maize sector, especially to rural economic development (FAO, 2022).

Losses due to post-harvest operations are not only the financial worth of the grain lost, but also a variety of indirect costs which may not be considered in traditional cost-benefit analysis (Hodges et al., 2011). The losses at the post-harvest stage were categorized by Hodges et al. (2011) as direct losses which are losses of actual grain, and indirect losses which include quality deterioration, price discounts, labor cost of removing damaged grain, distress sales and health-related costs due to contaminated grain. In an estimate of the economic losses due to post harvest losses (PHL), their study estimated that roughly 30%-50% of the total losses are indirect losses (Hodges et al., 2011). This suggests that losses caused by quality deterioration are as costly as physical losses, especially in markets with high grading requirements and lower price for low quality grain (Affognon et al., 2015). Therefore, post-harvest losses reductions should be targeted not only at retaining grain quantity but also ensuring quality of grain through the value chain (FAO, 2022).

Losses due to grain quality are of special concern in maize markets as quality is the key determinant of market prices and consumer acceptability (Kumar & Kalita, 2017). According to Kumar and Kalita (2017) maize with moderate insect damage and discoloration or quality defects are usually sold at 20-30% less than premium grade maize. Grain with significant proportion of broken kernels may be rejected by formal buyers and processors, or may be valued at 40-60% less, for more severe damage (Kumar & Kalita, 2017). These quality-related penalties place a significant dent in the farmers incomes, even if the physical losses seem relatively small (Hodges et al., 2011). Maize is also noted to have poor grading systems and low transparency in its marketing, often pushing farmers away from investing in quality improvement measures due to the lack of premium prices for higher quality maize (Kumar & Kalita, 2017). This perpetuates persistent low incomes in the maize value chain due to poor post harvest management (PHM) practices (FAO, 2022).

Similar evidence also shows that post harvest losses constitute substantial loss of productive resources used in the production of these crops (Mvumi et al., 2022) in Zimbabwe. Mvumi et al. (2022) estimated that smallholder maize farmers lost about USD 92 per hectare, which is about 15-20% of the total production cost. The losses at national level equate to an estimated loss of USD 45 million to USD 90 million of wasted agricultural resources per year (Mvumi et al., 2022). It also noted that a significant proportion of the grain lost due to post harvest losses was used internally, such that some of the economic losses were effectively externalized as health risks from the consumption of poor quality grain (Mvumi et al., 2022). It is clear from this finding that the 3 pillars of post harvest loss – economic, nutritional and food safety are interconnected.

There are several studies that have shown that investment in better storage technology can lead to significant economic benefits for smallholder farmers, and help to minimise losses and maintain grain quality (Tefera et al., 2021; Mvumi et al., 2022). For instance, hermetic storage bags have been proven to cause substantial decrease in insect damage and storage losses, and this strategy has relatively low investment cost (Tefera et al., 2021). It is estimated that the cost of the hermetic storage bag is about USD 2.50 and will last for three to four seasons, which is equivalent to USD 12–16/tonne of grain per season (Mvumi et al., 2022). Farmers can expect to save an estimated USD 25-35 per tonne annually by reducing storage losses from about 18.7% to 1.2% and the return on their investment will be 1.5 to 2.5 times the investment costs within a single production season (Mvumi et al., 2022). Even with these positive economic benefits, adoption is still limited due to the lack of liquidity, limited access to credit facilities, and poor availability of storage technologies in rural markets (Tefera et al., 2021; Mvumi et al., 2022).

Post harvest losses also have significant impacts on household food security and livelihood resilience (World Bank, 2022; FAO, 2022). Households with high post harvest losses tend to have lower food self-sufficiency periods than households with lower post harvest losses rates (World Bank 2022). The empirical evidence shows that households with post harvest losses > 20% continued to be food self-sufficient for about 7.2 months per year while the food self-sufficiency duration for households with losses < 10% was about 10.4 months per year (World Bank, 2022). Moreover, every 10% rise in post-harvest losses was correlated with a decline in food self-sufficiency of the individual households and significantly greater risk of selling distress

assets, such as livestock in order to feed oneself and family (World Bank, 2022). This result shows that not only do these post-harvest losses negatively impact on the incomes but they also make the rural households economically and climatically less resilient and more prone to poverty and food insecurity, as it can be seen in the following literature: (Affognon et al., 2015; FAO, 2022).

2.5.4 Empirical Review of the Existing Strategies and Recommendations for Loss Reduction.

The impact of post harvest loss (PHL) reduction on food security, on income generation and on agricultural sustainability has brought the subject into increased considerations by researchers, governments and development agencies (Affognon et al., 2015; FAO, 2022). The present experience – and others derived from the programme – indicates that a multi-pronged technological, educational, and institutional approach is needed for successful PHL reduction, rather than a single solution (Affognon et al., 2015). The existing strategies were classified into three general categories: technological interventions, capacity building interventions and institutional interventions, using a meta-analysis of post-harvest loss interventions in Sub-Saharan Africa (SSA) conducted by Affognon et al. (2015). The study found that interventions based on a combination of technical, behavioural, and market constraints were generally more successful in reducing post-harvest losses in a sustainable and long-term manner than were interventions focusing on either technical, behavioural or market constraints alone (Affognon et al., 2015).

Technological interventions are consistently found to be one of the most effective technologies which can be used to reduce storage losses in maize and other cereal crops (Tefera et al., 2021; FAO, 2022). The losses caused by traditional storage structures used by smallholder farmers were estimated at around 90-95% less with the hermetic storage systems by Tefera et al., 2021. The technologies operate by creating a sealed environment that hinders insect growth and lower deterioration of grains without the use of chemical insecticides (Tefera et al., 2021). Although they are effective, adoption rates were still relatively low ranging from 5% to 15% in many rural communities because of their high initial cost, lack of awareness and limited access to distribution networks (Tefera et al., 2021). Hence, the authors suggested providing targeted

subsidies, providing credit facilities at affordable costs and establishing distribution systems at the village level to promote access and uptake among resource-poor farmers (Tefera et al., 2021).

Capacity building interventions also have a potential to have substantial impact in decreasing post harvest losses due to better knowledge and practices of farmers (World Bank, 2022; Stathers et al., 2020). Stathers et al. (2020) assessed a participatory training programme that reached some 3,500 farmers in Tanzania, Malawi and Zimbabwe, and concluded that the training definitely had a positive impact on farmers' post-harvest management skills. The programme addressed important issues like optimum harvesting periods, drying of grains, moisture testing, identification of pests and use of hermetic storage technologies (Stathers et al., 2020). The results indicated a decrease in storage losses of ~7.2 percentage points for the households that participated in the intervention, with more noticeable changes from the farmer field schools and practical demonstrations (Stathers et al., 2020). The results indicated that having the right information is a critical factor in determining post harvest management outcomes, and can be used as a tool to support technological interventions in reducing losses (FAO, 2022).

Studies carried out in Zimbabwe have emphasized the need for proper grain protection practices and integrated pest management (IPM) in minimizing losses during grain storage (Mvumi et al., 2022). Even though the use of chemical grain protectants was common, many farmers who used them did not apply them following the recommended procedures as reported by Mvumi et al. (2022). The study revealed that nearly 64% of farmers used the wrong dosage and 41% used the treated grain stored in sacks that were contaminated or previously infested with the pest, which means that there is the potential for reinfestation and for the chemical treatments to be ineffective. The results suggest that chemical control may be inadequate to control storage pests. Thus, the authors proposed the use of IPM strategies involving better grain handling practices, hermetic storage systems, botanical pesticides, and clean up, to achieve more sustainable pest control results (Mvumi et al., 2022).

World Bank (2022) and FAO (2022) also identified institutional and policy interventions as playing an important role in effective post-harvest loss reduction strategies. The World Bank (2022) recognized that governments have an important role to play in investing in post-harvest infrastructure in rural areas, enhancing extension services, and facilitating access to modern storage technologies. The report suggested to increase the capacity of rural drying sites, improve

AGRITEX capability to offer post-harvest advisory services, and promote access to hermetic storage by offering subsidies and credit schemes (World Bank, 2022). The provision of better rural market infrastructure and timely payment in formal marketing systems, in addition, would be able to incentivize more farmer participation in formal markets and lower the pressure to sell distressed produce in informal markets (World Bank, 2022). This institutional assistance can provide a conducive platform to farmers to implement better post-harvest practices and technologies (FAO, 2022).

Experiences from other African countries provide additional evidence on effective strategies for reducing maize post-harvest losses at scale (APHLIS, 2023). APHLIS (2023) reported that Rwanda successfully reduced national maize post-harvest losses from approximately 25% to 12% over a five-year period through coordinated investments in storage infrastructure, farmer training, and market development programmes. In Kenya, large-scale dissemination of hermetic storage bags reached approximately 400,000 farming households and contributed significantly to reductions in storage losses and pest infestations (APHLIS, 2023). Similarly, community-based grain drying initiatives implemented in Malawi improved grain quality and reduced losses associated with poor drying practices and mould contamination (APHLIS, 2023). Across these case studies, strong political commitment, continuous financial investment, effective extension support, and sustained stakeholder collaboration emerged as key factors underpinning successful post-harvest loss reduction efforts (APHLIS, 2023; FAO, 2022). These experiences suggest that meaningful and lasting reductions in maize post-harvest losses require coordinated interventions that combine technology, farmer education, institutional support, and favourable policy environments.

2.6 Research Gaps Synthesis

From the literature review the following gaps have been identified which this study will aim to fill. Firstly, there is no published research available on the occurrence of PHL in Ward 5 Chingwere: as PHL is documented to vary by sub-national area, ward-specific evidence is vital and this study is the first to quantify this. Existing Zimbabwean studies have concentrated on storage losses, and have little quantified at drying, shelling and marketing stages; this study quantifies losses at each point in the value chain.

Additionally, there is a lack of systematic documentation of farmers' own assessments of the feasibility, acceptance and cost of various technologies for loss reduction. Technically effective technologies (such as metal silos) may not be economically viable or culturally acceptable. This research provides farmer perceptions and preferences. Very few studies explicitly relate post harvest losses to household food security and income outcomes explicitly in quantitative terms. This study attempts to measure the relationship between the duration of food insecurity and household income and food security level. Although the effectiveness of loss reduction technologies is proven, there is no systematic assessment of interventions that are feasible and acceptable in Ward 5, and this study evaluates existing strategies, and makes recommendations based on those evaluations. This study therefore aims to inform the evidence base for contextually appropriate, effective and feasible interventions in Ward 5, Chingwere by filling in these gaps.

2.7 Chapter Summary

The chapter summarizes literature regarding operational definitions of the six key words used in the study, PHL, maize value chain, smallholder farmers, food security, hermetic storage and grain quality. It introduced the theoretical framework (Sustainable Livelihoods Framework, Diffusion of Innovations Theory) and conceptual framework of independent, intervening and dependent variables and then reviewed the empirical literature in an objective manner, identifying five key research gaps which this study aimed to tackle. The methodology employed in the investigation of these issues in the study area of Ward 5, Chingwere is presented in the next chapter.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The research methodology in this chapter is research design, study area, target population, sampling, data collection method, data collection instrument, data analysis techniques and ethical considerations.

3.2 Research Design

The study employed a mixed methods case study design that incorporated qualitative and quantitative approaches in one case (Ward 5, Chingwere) suitable for understanding a contemporary phenomenon in depth in its real world context (Yin, 2018). The design was appropriate for the study as it was context based and sought evidence at the ward level, rather than attempting broad generalisation, combined “what” questions (extent and quantities of losses) with quantitative measurement of the evidence with “how” and “why” questions (causes, perspectives, feasibility) with qualitative exploration and allowed for methodological triangulation, and the boundaries between the phenomenon (PHL) and the context (Ward 5 farming systems) were not clearly separable (Yin, 2018; Creswell & Creswell, 2018).

The study took a convergent parallel mixed methods design (Creswell & Clark, 2017) to gather both quantitative and qualitative data simultaneously, analyse each type individually, and then integrate during data interpretation to provide an understanding of the magnitude and value of losses, and capture the farmers' lived experiences and constraints. The use of mixed methods was

justified by the multidimensionality of PHL, its physical, economic, social and behavioural aspects. A quantitative approach alone would be able to determine the size of losses, but not account for the reasons that farmers persisted in loss-causing behaviours, while a qualitative approach alone would capture farmer perceptions but not quantify losses or the economic impact. Both helped to produce credible estimates and actionable findings (Creswell & Clark, 2017; Bryman, 2016).

3.3 Study Area.



Source: ZIMSTAT (2022) & Survey Department of Zimbabwe (Base Map)

Figure 3.2 Locational Map of Mhondoro Ngezi District

The study was carried out in Ward 5 (Chingwere) of Mashonaland West Province (Mhondoro Ngezi Rural District Council) in the Chingwere area, Mhondoro Ngezi district of Mashonaland West province located 120 km to the southwest of Harare between latitudes 18°30' and 19°00'S and longitude 29°45' to 30°30'E which is bordered by Chegutu, Zvimba, Sanyati and Chirumanzu Districts in Mashonaland West Province (Mhondoro Ngezi Rural District Council, 2024). Chingwere is comprised of villages such as Chingwere Centre, Chikombedzi and

Mupfure, which are accessed through the Harare-Bulawayo highway, and the closest town is Chegutu (35 km east) while Ngezi is the district administrative centre (25 km north).

The district is in Natural Region II where the rainfall is moderate to high ranging between 700 – 1000 mm and with only one rainy season from November to March, this region is regarded as good agricultural land for maize, tobacco, cotton and soyabean on fertile red clay loam soils (Vincent & Thomas, 1961; Mugandani et al., 2012; Nyamapfene, 1991). But the rainfall data for Chegutu (1980-2023) indicates that the rains are getting delayed in the mid-season with excess rains during the March to April harvest periods which directly affects the drying opportunities and the risk of mould (Meteorological Services Department of Zimbabwe, 2024).

The farming system in Ward 5 represents the typical arrangement of the smallholder farming system which is dominated by maize crop cultivation covering 70-80% of the land, the remaining space together with groundnuts, cowpeas, sunflower and vegetables is used for cattle, goats and chicken farming activities (AGRITEX Mhondoro Ngezi, 2024). Most tillage is done by oxen, 60% of farmers use basal fertiliser and 55% use top dressing, and more than 70% of farmers are using hybrid seed with 30% still using retained seed. Limited post harvest infrastructure: most households use traditional granaries (dura) made from untreated poles, wire mesh and mud plaster, 10-15% have adopted hermetic storage while drying is largely on bare ground with only 8-10% having tarpaulins and concrete platform (Mhondoro Ngezi District Annual Agricultural report 2024).

Ward 5 was purposively selected for four reasons, it is representative of the smallholder maize systems dominating production in the country in Mashonaland West; AGRITEX consultation suggested PHL is a significant problem but not quantified; the ward was diverse in farming practice, technology adoption and market access for comparison; the researcher had built rapport with communities and extension for access.

3.4 Target Population

The target population included all smallholder household and those households that produced maize during the 2023/24 season in Ward 5. The ward has a total of 5587 people (2705 males and 2882 females) in about 950 to 1100 households of which about 350 to 400 households would

be classified as such (Ward population 2024, ward area is the ward of Ngezi Rural District Council, 2024; AGRITEX).

3.5 Sampling Procedures and Sample Size Determination

The sampling frame comprised a farmer register from the AGRITEX obtained at ward level with cross verification using key informant interviews (KII) with village heads and extension officers, identifying 367 households identified as farmers involved in maize farming in the villages in the ward.

Sample size was calculated with Cochran formula for finite populations (Cochran, 1977; Bartlett, Kotrlik, & Higgins, 2001) which is commonly used in agricultural research. The formula is:

$$n_o = (Z^2 \times p \times q) / e^2$$

Where:

n_o equals the required sample size

Z equals the Z score corresponding to the desired confidence level (1.96 for 95% confidence)

p equals the estimated proportion of the population with the characteristic of interest (0.5 used for maximum variability)

q equals 1 minus p

e equals the desired margin of error (0.07 or 7%)

Calculation:

$$n_o = (1.96^2 \times 0.5 \times 0.5) / (0.07)^2$$

$$n_o = (3.8416 \times 0.25) / 0.0049$$

$$n_o = 0.9604 / 0.0049$$

$$n_o = 196$$

Since the total population is finite (367 households), the finite population correction formula was applied:

$$n = n_o / [1 + (n_o - 1) / N]$$

Where:

n equals the final adjusted sample size

N equals the total population (367)

Calculation:

$$n = 196 / [1 + (196 - 1) / 367]$$

$$n = 196 / [1 + 195/367]$$

$$n = 196 / [1 + 0.5313]$$

$$n = 196 / 1.5313$$

$$n = 128$$

Thus, a sample size of 128 households was needed. This sample size is about 35% of the total maize farming households in the ward, and it has enough statistical power ($\beta > 0.80$) for detecting medium effect sizes (Cohen's $d = 0.5$) in comparisons between subgroups at $\alpha = 0.05$ (Cohen, 1988).

Stratified random sampling was employed to ensure representation of key farmer categories, based on the conceptual framework, which identified as key drivers of loss levels: storage technology (traditional granary only; hermetic storage; other or modified) and market participation (commercial; subsistence, selling 30% or less; subsistence, selling more than 30%). Households were randomly selected from the numbered sampling frame within each stratum with equal selection probability and representation of key subgroups within each stratum.

Fifteen key informants were purposively selected to include agro-dealers and input suppliers (2), farmer group representatives (3), traditional leaders and village heads (4), NGO staff (3), and the depot manager at GMB, Cheguti (1) who are professionally involved with farmers on post harvest issues.

3.6 Data collection method and instrument

Because post harvest losses are multidimensional in nature, a multi method and multi instrumental approach was used in this study. All the instruments were designed on the conceptual framework and literature search, and then pilot tested with 10 non-sample farmers in another ward to check clarity, comprehensiveness and appropriateness.

The main quantitative instrument was a structured questionnaire in the home which was divided into six sections; demographics, production and harvest, post harvest practices, losses, marketing and food security. It asked primarily closed-ended questions with pre-coded categories, with

some open-ended questions, and quantities were recorded in local units (buckets, tins, bags) and converted to kilograms based on factors that were established during the piloting.

An interview guide was created for key informant interviews, which was semi structured. The guide included the following sections: perception of extent and trends of post harvest losses in Ward 5, identification of key causes of post harvest losses and loss hotspots, observations of farmer practices and constraints, assessment of existing extension and support programs, feedback on possible and appropriate interventions, and recommendations for policy and programmatic action. The semi structured format allowed for flexibility to explore themes that emerged during the interviews and also allowed for consistency across interviews on key themes.

The storage structure type, condition and construction materials, and evidence of pest infestation (live insects, webbing, bore dust, damaged grain) were directly observed and documented using an observational checklist, as were drying practices and facilities, and shelling equipment and method, and general sanitation of grain storage areas. Observations were made on a standardized form which was subsequently documented photographically when permission was granted. The triangulation and cross-checking of observations with self-reported information from the household survey were carried out.

Approximately 500g of grain samples from a sub-sample of 40 households across the storage technology categories were taken and objectively tested for moisture content using a portable grain moisture meter, broken kernels, foreign material and mould contents by hand sorting 300g sub-samples, giving objective validation of reported losses in grain quality.

Table 3.1: Data Collection Matrix

Specific Objective	Data required	Data source	Collection Method	Analysis method
Identify key actors and roles	Value chain actors, functions, marketing channels	Farmers, key informants	Household survey, KIIs	descriptive statistics and thematic analysis
Determine causes and hotspots	Stage-specific losses, pest incidents, practices	Farmers, observations	Survey, observational checklist, grain quality assessments	descriptive statistics and thematic analysis
Quantify economic and qualitative losses	Grain lost(kg%), quality parameters, prices	Farmers, GMB traders	Survey, market survey, grain quality assessments	descriptive statistics and ANOVA

Evaluate strategies and propose recommendations	Current practices, barriers and preferences	Farmers, key informants	survey, KIIs	descriptive statistics and thematic analysis
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3.7 Data Collection Procedures.

Before data collection, the researcher obtained ethical clearance from Bindura University of Science Education, secured institutional approval from Department of Agricultural Economics and Extension, as well as from the village heads in the Ward 5 in Mhondoro Ngezi Rural District Council, and the permission of the two research assistants from the AGRITEX district offices who were fluent in Shona and knowledgeable about the study area.

The data collection was done for 6 weeks from October to November 2024 during the post harvest period when the losses were being observed. The questionnaire was administered face-to-face using a back translated version of the questionnaire in Shona, and the interviews lasted 45-75 minutes, depending on availability.

Key informant interviews (KIIs) were audio recorded after gaining permission or written notes taken after the interview was refused and took between 45 and 90 minutes. After home visits, storage units and the condition of the grain was observed and documented on a standardised checklist and grain samples were composited, sub-sampled to 500g, and analysed within 72 hours at Bindura University.

The research assistants were trained for two days, covering objectives, administration, ethics and conversion factors. Pilot testing of instruments with 10 non-sample farmers was conducted and ambiguous questions were modified. All data was double entered and validated, and the principal researcher supervised data collection, conducted spot checks, and re-contacted 10% of samples randomly to double-check key data and then debriefed the data on a daily basis.

3.8 Data Analysis

The descriptive statistical techniques was used in coding, entering and analysis of quantitative data. Demographic data, value chain actors, value chain marketing methods, value chain loss reduction strategies, and loss reduction hotspots were summarized in terms of frequencies, percentages, means and standard deviations. Data were displayed in the tables, figures and bar graphs for comparison and interpretation. The key informant interviews and open-ended

questionnaire responses were used to gather qualitative data, which was then analysed thematically according to Braun and Clarke's (2006) approach to thematic analysis. Integrating quantitative and qualitative findings during interpretation enabled a full understanding of the maize value chain post-harvest losses in Ward 5, Chingwere.

3.9 Ethical Considerations

The principles for research with human subjects (British Educational Research Association, 2018; Resnik, 2020) have been followed in this study. The participants received a clear description of the aim of the research, the research procedures, potential risks, potential benefits, and the rights. Shona was used for all oral communication and a written information sheet was used for all additional information. All participants gave written informed consent before data collection. Consent was also obtained verbally for those with limited literacy, and the information sheet read aloud and witnessed.

There was no coercion or inducement used, and participation was strictly voluntary, meaning that any questions were optional, and there were no repercussions for answering any or none of them. Personal identifiers have been substituted with study codes, data have been kept on password protected computers that can only be used by the research team, findings have been reported in an aggregate fashion and direct quotes have been attributed to the participant categories instead of individual names.

The study did not cause any risks to the subjects. The biggest drawback was the time needed to conduct interviews, which were set up at each participant's convenience to minimize disruption. Around 500g of grain per household were removed for sampling, a very small amount that Participants were warned beforehand will not impact household food security.

Following analysis, a meeting for feedback in Ward 5 and a summary meeting with AGRITEX and the Rural District Council will follow with participation of community leadership throughout. The protocol was approved by the Bindura University Research Ethics Committee, Mhondoro Ngezi Rural District Council and AGRITEX.

3.10 Chapter Summary.

This chapter illustrated the mixed methods approach to the design of the study that included both quantitative and qualitative methods in Ward 5, Chingwere, described the geography of the study area, agro-ecology of the study area, farming systems in the study area, the target population and provided details on the stratified sample of 128 households obtained using Cochran formula. Data collection procedures were strictly followed with rigorous training, supervision and verification of enumerators, and the use of multiple pilot-tested instruments, a structured questionnaire, key informant guide, and observational checklist and grain quality protocol. Thematic analysis, a form of content analysis, was used to integrate with descriptive and inferential statistics and was addressed throughout the analysis and in the interpretation. The results are reported in the following chapter.

CHAPTER 4: RESULTS AND FINDINGS

4.1 Introduction

The post harvest losses of smallholder maize systems are a result of interaction of a complex mix of technological, socioeconomic and institutional factors. The extent of these losses, the distribution of these losses across the value chain and the way in which farmers react to these losses to cope with them is highly variable even within a single ward. This chapter discusses the empirical results that shed light on these dynamics in Ward 5 of Chingwere in Mhondoro Ngezi District. The findings come from a structured household survey conducted among 128 maize farming households (35% of the total of 367 household surveyed) in the ward, 15 key informant interviews (KIIs) with extension officers, village heads, traders and NGO representatives, and direct observation of the post-harvest practices for all 128 households, as well as grain quality assessments for a sub-sample of 40 households, all of which followed the procedures outlined in Section 3.7, including pilot testing of questionnaires and verification of 10% of responses. The chapter is structured around the four objectives: Section 4.2 covers demographic characteristics, Section 4.3 outlines value chain actors, Section 4.4 outlines loss causes and hotspots, Section 4.5 quantifies economic and qualitative losses and Section 4.6 outlines strategies and recommends for them. Section 4.7 summarizes the main findings.

4.2 Demographic Characteristics of Participants

4.2.1 Gender and Age Distribution of the Household Heads

Males (68%) made up the bulk of the household heads followed by female headed households (32%) which is consistent with the typical household structure of smallholder farmers in Mashonaland West Province where males are mostly the household heads while females are actively involved in farm production activities (AGRITEX Mhondoro Ngezi, 2024). While fewer, female-headed households often have further restrictions on accessing post-harvest resources and technologies.

The majority of respondents (48%) were middle aged (36 – 55 years), the group most active in the economy, elderly farmers (56 & older) accounted for 37%, and youth (18 – 35 years) accounted for 15% of respondents which is indicative of ongoing rural-urban migration as youth move to pursue non-farm employment (ZimVAC, 2024). Most youths have migrated to Chegutu or Harare for employment and those who are still in their home provinces are keeping their parents' farm or waiting for opportunities to leave (KII-AGRITEX-01).

Household Size and Labour Availability 4.2.2

The average household size was 5.8 persons (SD = 2.4), with 52% having four to six persons, 23% having seven to nine persons, 18% having one to three persons and 7% having ten or more persons in their households.

There were an average of 3.2 working-age adults per household (SD = 1.6) available for agricultural labour. During the peak periods, labour constraints at post harvest, especially harvesting and shelling delayed post harvest activities, which led to losses as one female respondent noted that everyone must harvest at the same time but they rarely have enough hands as her husband is working at another location called Chegutu leaving most of the work to her (HH-047, Female).

4.2.3 Education Level of Household Heads

Most of the heads of households completed primary education (42%) or secondary education up to Form 4 (41%), with 9% having no formal education and 8% having education beyond Form 4 (5% Form 5/6, 3% tertiary). The lack of formal education relates to post-harvest technologies, including the uptake of new technologies, which may require simple numeracy skills like using moisture metres and following recommended rates of application of grain protectants. For less

educated farmers, demonstration based extension techniques may be needed, rather than written materials.

4.2.4 Land Holding and Maize Cultivation

Maize cropped an average of 1.6 hectares (range 0.5 to 3.5 hectares) which was approximately 57% of cultivated land, as was estimated at ward level in Chapter 1, and was within the range estimated at ward level.

4.2.5 Sources of Income

Of the respondents, over half (55%) reported that their main source of income was from maize sales, while 14% said they earned income from off-farm activities, 11% from livestock sales, 8% from other crops sales, 6% from remittances, 5% from artisanal mining and 2% from small business. The percentage of households that reported more than one income source other than maize, however, was 86%, which suggests diversified livelihood strategies, similar to Scoones et al. (2019). One Village Head said that, they are not living on maize and needs for everyday basic living are daily; thus, they do piece work, sell livestock or dig for gold daily (KII-VillageHead-03).

4.2.6 Access to Extension Services

As far as contact with extension was concerned, 18% of respondents said they never got a visit, 32% got one visit each season, 38% got two to three visits per season, and only 12% got monthly or more frequent visits. This is due to the high ratio of farmers to extension agents with one agent serving about 1200 farmers in different wards. An extension officer confirmed that when two-thirds of the wards have been identified with fuel issues, he would not be able to reach all of them and would instead visit lead farmers, and would only visit post harvest issues if they had been damaged (KII-AGRITEX-02).

4.3 Key actors in the maize value chain

This section tackles the first specific objective of identifying the key actors and their role in the maize value chain in Chingwere ward. The findings were obtained through the key informant interviews, direct observation and open-ended survey responses based on qualitative data collection as described in Chapter 3.

4.3.1 The mapping of the Value Chain Actors

The maize value chain in Ward 5, Chingwere is shown in figure 4.1. The chain starts with input suppliers, agricultural chemical, fertilizer, and seed suppliers for smallholder farmers. Maize is then sold by farmers via three important routes, that is, via the Grain Marketing Board (GMB), village traders, and direct farm gate sales. The maize traded via GMB and village traders eventually reaches the millers, retailers or consumers and farm gate sales refer to direct transactions between households and farmers. There are support services available in all the stages of the value chain, offered by AGRITEX and NGOs.

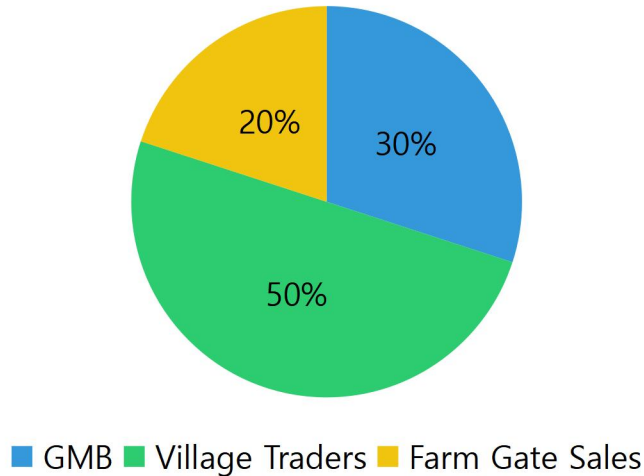
Table 4.2 MARKETING CHANNELS, PROFITS AND LOSSES

Marketing Channel	Farmers Using Channel (%)	Average Price (USD/kg)	Main Benefit	Main Loss
GMB	30	0.35	Higher prices	Delayed payments
Village Traders	50	0.28	Immediate cash	Lower prices
Farm Gate Sales	20	0.25	No transport costs	Lowest bargaining power

The marketing channels used by the farmers is given in Table 4.2. The majority (50%) of respondents stated that village traders were the main point of sale for their products, followed by GMB (30%) and farm gate sales (20%). GMB was able to offer higher prices but many farmers chose the village traders as they could get cash for their produce immediately.

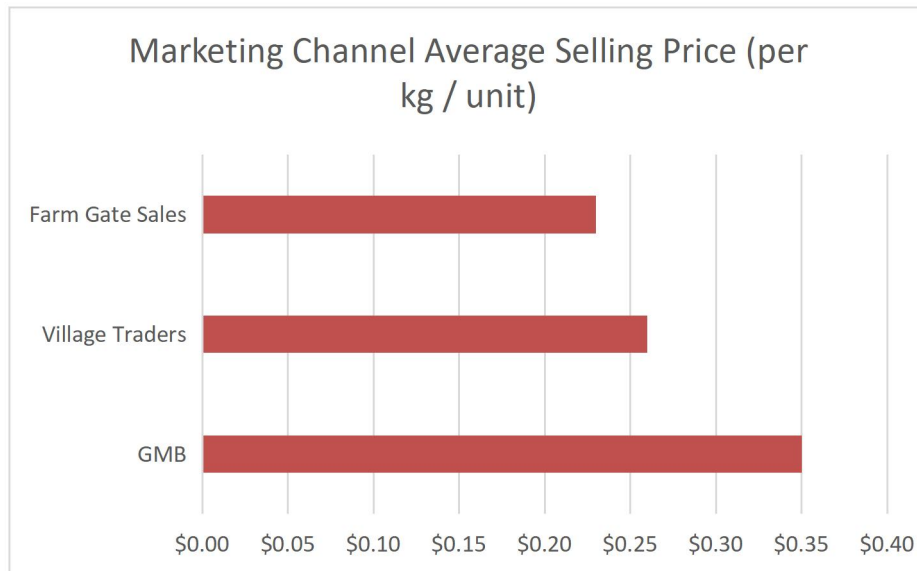
Figure 4.3 Distribution of Farmers by Marketing Channel

Table 2: Distribution of Farmers by Marketing Channel



As indicated in figure 4.3 the predominant marketing channel was village traders. This implies that farmers care more about having easy access to cash than they do about lower prices as compared to formal markets.

Figure 4.3.1 Average Selling Price by Marketing Channel



For example, GMB had the highest prices, with lowest returns from farm gate sales, as shown in figure 4.3.1. This illustrates the profit/loss at each stage of marketing.

4.3.2 Roles and Functions of Key Actors

Maize is produced by the smallholder farmers who then perform activities from production to selling the maize through three different channels: to GMB depot in Chegutu (approx. 35 km away), to village based traders or selling through the farm gate.

One person explained his reason for his sales channel, that the GMB gives a better price during the sales (around USD 0.35 per kg) but cannot be paid at the gate, waiting weeks before getting paid, while traders pay cash at the gate and give a price of USD 0.25 to 0.30 per kg; it is better to sell to the traders when money is urgently required (HH-082, Male).

Traders in the local village were identified as critical but over-looked, and they operate with relatively small stocks of maize across 10 to 50 households and are estimated to sell 60 to 70% of maize in the ward, which is similar to the estimates of Jayne et al. (2010). Traders also caused quality-related losses by rejecting or discounting (by 30-50%) grain that was visibly infested or had a high moisture content, encouraging the farmers to buy their grain formally and use or dispose of lower quality grain at home.

The importance of AGRITEX in the post-harvest stage was identified as limited but potentially significant: all 15 KIs confirmed that they valued the services of the organization for providing Extension services in production; however only four reported that they received any training on the post-harvest stage, and production training is the primary focus of Extension curricula. If two of five tonnes are lost, then the amount of help extension can provide farmers to produce more is incomplete, but there are no resources in extension to show, such as moisture meter and hermetic bag (KII-AGRITEX-01).

The main formal market is the GMB in Chegutu with standardised pricing, transparency in grading and the capacity to sell in bulk, however farmers reported that they were taking 4 to 6 weeks to be paid for the grain, grain was rejected if it had 2% or more insect damage, USD 10 to 20 per tonne was being charged for transporting the grain and farmers reported long queues. One farmer reported bringing the crop to the GMB and the moisture passing, but too much broken grain from shelling made it a Grade B which he was paid 30% less than Grade A so he had no option but to take it (HH-114, Male).

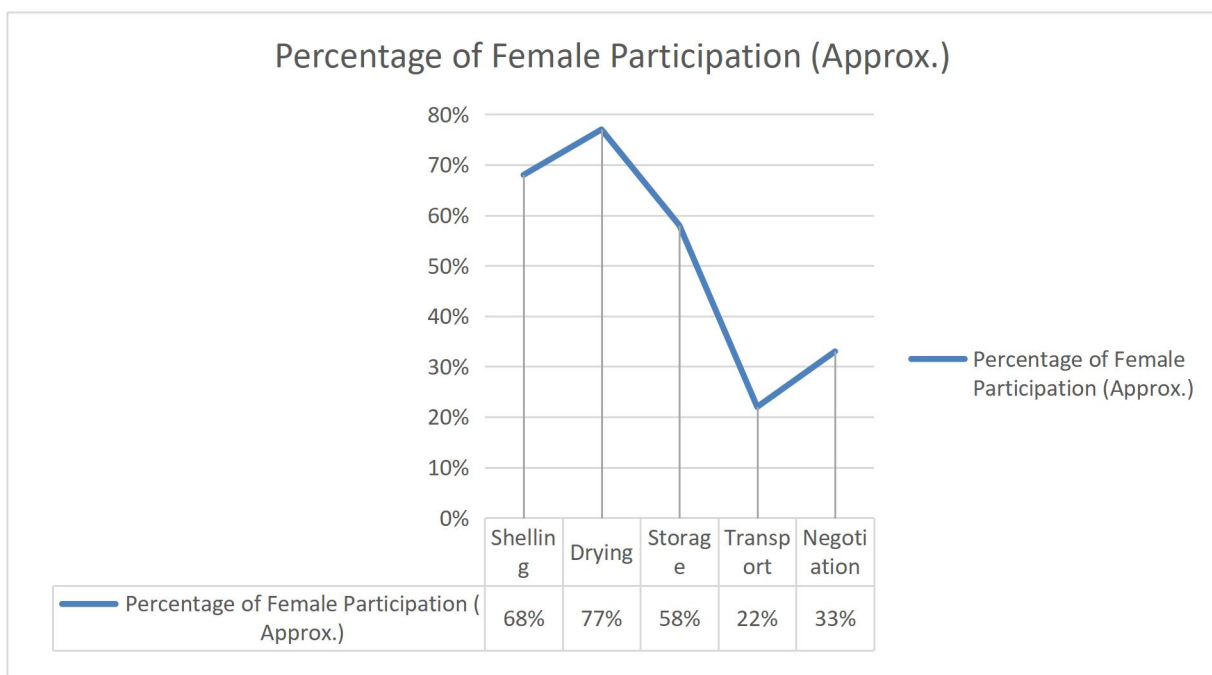
4.3.3 Gender Dimensions in Value Chain Participation

Table 4.3.3 Gender Dimensions in Value Chain Participation

Activity	Male (%)	Female (%)
Shelling	32	68
Drying	23	77
Storage Management	41	59
Transport	79	21
Price Negotiation	66	34

Table 4.3.3 indicates that the gender differences are significant in terms of involvement in shelling, drying, storage and transportation activities with women showing greater participation than the men, and in respect of price negotiations, with men showing greater participation than women.

Figure 4.4 Female Participation in Value Chain Activities



4.4 Causes and Hotspots of Post Harvest Losses

This section focuses on the second specific goal of the study; identification of causes and hotspots of post-harvest losses in the maize value chain. The results are a synthesis of the quantitative loss estimates obtained from the household survey (128 farmers), the grain quality assessment results from the sub sample of 40 farmers' households, and qualitative results from key informant interviews (KIIs) held with 15 participants. The triangulation of method as suggested in Chapter 3 increases the validity of the results.

4.4.2 Post Harvest Loss Estimates, by Region

Storage losses were the highest hotspot at 19% (SD = 8%), as reported by Affognon et al. (2015) and Mvumi et al. (2022) which gave 60-70% of total PHL as storage losses. Drying losses averaged 6% (SD = 3%), shelling losses averaged 4% (SD = 2%) and harvest, transport to homestead and transport to market losses averaged 2%, respectively.

The mean percentage losses reported by each stage of post harvest value chain farmers are given in Table 4.4 with standard deviations and ranges.

Table 4.4.1: Mean Post Harvest Losses by Value Chain Stage

<i>Value Chain Stage</i>	Mean Loss (%)	Standard Deviation (%)	Minimum (%)	Maximum (%)
<i>Harvesting</i>	2	1	0	8
<i>Transport to homestead</i>	2	1	0	5
<i>Drying</i>	6	3	0	15
<i>Shelling</i>	4	2	0	12
<i>Storage</i>	19	8	2	45
<i>Transport to market</i>	2	1	0	7
<i>Total Estimated Loss</i>	35	11	8	68

The total estimated losses across the post-harvest chain averaged 35%, higher than the post-harvest losses ranging between 20 and 35% across the provinces in Chapter 1, while the losses at household level ranged from 8 to 68%.

4.4.2 Storage Losses as the Primary Hotspot

As a result of the dominance of storage, the study investigated the storage practices in detail. Most (73%) stored maize only in a traditional dura granary, which had the highest average losses (23%). Losses were dramatically lower in the hermetic bag users (5%), the lowest in the metal silo users (3%), 18% in the recycled chemical bag users, while the users of modified granaries and hermetic bags (2%) had losses of 5%. These structural flaws were evident in the direct observations of traditional granaries, including gaps in the walls for insect and rodent access (82%), lack of ventilation leading to moisture in granaries (67%), absence of rodent guards (91%), and thatch roofs that were in poor condition, where rainwater could penetrate (43%). The differences in storage losses between traditional and hermetic storage technologies were determined using an independent samples t-test.

It was identified that the main hotspot of the post harvest losses in Ward 5 was storage. The household survey results showed that the highest proportion of maize losses was caused by storage losses, with 19% contribution to the total losses among the sampled households. From the observation, the granary used for storing the harvested food items was found to be 73% traditional granary and 14% hermetic bags. In 78% of the storage structures, signs of infestation were found and in 54% of the grain samples visible mould was observed. Based on this findings, it showed that the storage losses were mainly due to poor storage facilities, pest infestation, inadequate ventilation and poor moisture management in the study area.

One farmer reported having a granary constructed by his father in 1995, which was repaired numerous times but was now infested with mouse holes in old wood with losses in the grain, and he could not afford a new granary or metal silo, nor could he get hermetic bags from the Chegutu agro-dealer (HH-056, Male) often enough.

Table 4.5 HOTSPOTS OF POST-HARVEST LOSSES

Rank	Value Chain Stage	Mean Loss	Interpretation
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		(%)	
1	STORAGE (Primary Hotspot)	19%	Storage Is The Major Hotspot Where Most Losses Occur.
2	DRYING	6%	Drying is the second highest hotspot requiring better practices.
3	SHELLING	4%	Shelling contributes to moderate losses and can be reduced with proper techniques.
4	HARVESTING	2%	Losses at harvesting stage are relatively low.
5	TRANSPORT TO HOMESTEAD	2%	Transport to homestead causes minimal losses.
6	TRANSPORT TO MARKET	2%	Transport to market has the lowest losses.

Table 4.5 is the ranking of the post harvest loss hotspots in order of severity. The largest losses were suffered in storage, making this the main hotspot.

4.5.1 Pest Infestation as a Primary Cause of Storage Losses

Insect infestation from storage was evaluated by grain sampling and farmer reports. The Larger Grain Borer (*Prostephanadanus truncatus*) was reported by 69% of the households with a mean loss of 11%, which was the highest for any single pest; the maize weevil (*Sitophilus zeamais*) was reported by 82% with 8% loss on average; the damage by rodents was almost universal (91%), but caused only 3% loss on average; while visible mould was a qualitative loss reported by 54% of the households.

Overall, 71% of the samples from the 40-household subsample in the GMAZ survey were assessed as grain quality with live insects, averaging 19 live insects per kilogram, which is much higher than the zero-tolerance threshold for Grade A and the five-per-kilogram limit for Grade B (Grain Millers Association of Zimbabwe, 2024).

The results indicate that there is a strong correlation between the storage conditions and the level of pests. Households using traditional storage technology had generally higher levels of insect infestation, rodent damage and mould contamination than households with improved storage technology. Pests were found in 78% of the storage facilities and poor storage conditions like wall gaps, lack of ventilation and lack of rodent guards were common. The conditions were conducive to the growth of pests and played significant roles in the quantitative and qualitative losses after harvesting.

4.5.2 Drying Losses

Drying losses averaged 6% which is the second hotspot after storage. The practice with the highest proportion of losses (7%) was drying maize on bare ground without covering, as grains stick to the ground, animals scavenge, wind scatter and overnight dew or rain causes mould. Losses of 5% were recorded for the 15% of households which covered their grain at night on bare ground, 6% for those covering with a tarpaulin or plastic sheet and 3% for those covering with a concrete platform. The difference in the amount of drying losses observed shows that the drying method of maize significantly affects the post harvest losses. The household that were drying maize on the bare ground suffered maximum losses, followed by those who were drying maize under tarpaulins and the concrete platform by a significant margin. The results of the observation were also found that 58% of the grain samples were contaminated with soil or foreign substances while 72% of households did not properly shelter the grain during rain. The results indicate that, better drying technologies and practices could considerably minimize the quantitative and qualitative losses in the study area.

Farmers recognized these losses, but identified a lack of resources as the main obstacle. One female respondent reported that although she could see the grain sticking to the soil, it would cost USD 20 to get one - money which she need for fertiliser or salt - while some farmers use old tobacco grading sheets to do the job (HH-091, Female).

4.5.3 Shelling Losses

Shelling losses averaged 4%. Only 15% of the households using hand shelling with no implement had 3% of grain broken and faced a 3% price drop, while 87% who used the manual method with a stick and beater experienced a 15% price drop and 6% broken grain. Hand shelling with no implement (9%) had 2% broken grain and a 5% price drop, whereas the 4% of households that rented mechanical shellers had the lowest amount of broken grain (2%) and a minimal 3% price drop. The low uptake of mechanical shellers was cited as the high cost of renting a sheller from USD 5 to 8 per hour and the requirement to transport the cobs to the sheller site which is located by a private renting company in Ngezi town, about 25 kilometers away from ward 5.

4.5.4 Causes of Losses as Perceived by Farmers

Perceived causes of PHL listed by farmers were: lack of proper storage (87%), insect pests (84%), lack of drying tarpaulins or sheets (80%), lack of money to implement improved technologies (78%), inadequate knowledge of drying practices (63%), rodent damage (59%), uncertainty about the weather (56%), lack of access to mechanical shellers (52%), and limited post-harvest extension advice (48%).

Lack of money to adopt technologies that can be understood as an economic constraint due to the poor economic competitiveness of the farmers was cited as the most important cause, and is consistent with the other two most important causes identified: lack of proper storage and insect pests.

One NGO key informant summarized the cyclicity of the problem “*Farmers do not have good storage facilities, so they lose grain, have less to sell, and have less money for hermetic bags/tarpaulins next season, and so on*” (KII-NGO-01).

4.6 Economic and Qualitative Losses

This section deals with the third specific objective of the project which is quantifying the economic and qualitative losses suffered as a result of post harvest losses. Findings combine economic farm data collected by farmers and tested grain quality data from the sub sample of 40 farmers, as well as market price data gathered from key informants at the Grain Marketing Board.

The results show that post harvest losses caused significant economic and qualitative losses to the farming households. The survey revealed that the average loss of grain was around 567 kg/ household, which equates to an estimated loss of USD 160 to USD 199/ household. Annual losses were estimated to be between USD 58,720 and USD 73,033 on the ward level. These losses reduced household income, hampering farmers' capacity to buy inputs for the next season and impacting household livelihoods.

Figure 4.6 Mean Post-Harvest Losses by Value Chain Stage

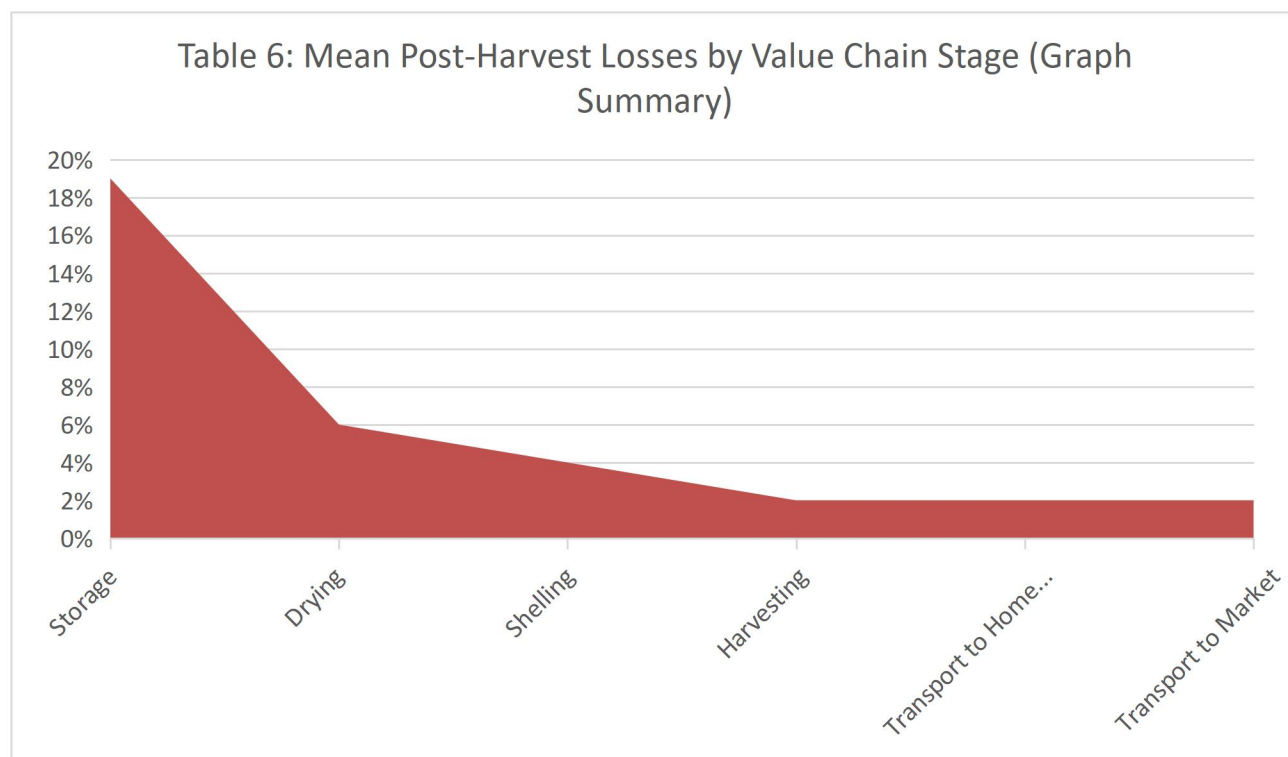


Figure 4.6 shows that there was no significant difference in mean post-harvest losses across all the value chain stages.

As seen in figure 4.6, storage is the most dominant hotspot where a lot of losses are experienced, followed by drying and shelling. There is a need for better drying practices and improved storage technologies as well. The larger the extent of the losses concentrated in the storage phase, the more critical the need for better storage facilities and pest management. The combined impact of drying and shelling losses on grain amount and quality further diminished the economic losses for farming households though this accounted for lesser percentage of total losses.

4.5.1 Economic Value of Quantitative Losses

Post harvest losses resulted in an average household losing about 567 kg of maize seasonally. Of the total loss, 309 kilograms or over 50 per cent were due to storage losses. The drying weight was 93 kilograms, shelling 67 kilograms, harvesting 38, transport to market 34 and transport to homestead 26 kilograms.

The estimated economic value of loss of grain at each stage of the post-harvest chain is shown in Table 4.6.1 using farm gate prices and official Grain Marketing Board prices.

Table 4.6.1 Economic Value of Post-Harvest Losses per Household

Value Chain Stage	Mean Grain Lost (kg)	Value at Farm Gate (USD)	Value at GMB Price (USD)
Harvesting	38	11	13
Transport to homestead	26	7	9
Drying	93	26	33
Shelling	67	19	24
Storage	309	87	108
Transport to market	34	10	12
Total	567	160	199

Note: An average of USD 0.28 per kilogram was reported by the farmers at the farm gate; At the time of this study, Grain Marketing Board price was USD 0.35 per kilogram.

The total economic loss at farm gate was USD 160 per household, at the GMB prices it was USD 199. At the ward level the total economic loss was extrapolated as USD 58,720/year and USD 73,033/year at farm gate and GMB prices respectively, which is a significant burden on the local economy and food security.

4.6.2 Quality Losses and Price Discounts

Table 4.6.2 summarizes the grain quality parameters and associated price discounts by grade classification.

Quality Parameter	Grade A (n=24)	Grade B (n=68)	Grade C (n=36)
Proportion of households (%)	19	53	28
Mean moisture content (%)	12	14	15

Mean insect damaged kernels (%)	1	5	12
Mean broken kernels (%)	2	6	10
Mean foreign matter (%)	0.4	1.2	2.8
Mean price received (USD/kg)	0.34	0.26	0.18
Discount relative to Grade A (%)	0	24	47

Quality deterioration resulted in significant price discounts: only 19% achieved Grade A (moisture below 13.5%, insect damage below 2%, broken kernels below 3%.

Significant price discounts were experienced because of quality deterioration – only 19% met Grade A (moisture below 13.5%, damaged by insects below 2%, broken kernels below 3%). Quality deterioration resulted in substantial price discounts for farmers. Households with Grade C had the highest moisture content, as well as higher levels of insect damage, cracked kernels, and foreign matter, with none of these households having grade A grain, and the mean selling price was USD 0.18 per kilogram, whereas the mean selling price for Grade A was USD 0.34 per kilogram. This was a 47% discount from the price, underlining the economic impact of poor post-harvest handling and storage practices.

Table 4.1 Grain Quality Parameters and Price Discounts by Grade

The mean price of Grade C grain was USD 0.18 per kg, which is 47 per cent lower than the price for Grade A grain. Farmers whose grain was downgraded to Grade C often reported that the grain was either refused, or that buyers—both Grain Marketing Board and informal traders—were willing to pay less than the cost of production.

One farmer said that he had brought 20 bags to the GMB and had been offered USD 0.15 per kg - which is below his fertiliser cost of USD 0.20 per kg of maize he grew and refused to sell the grain and took it home and only had USD 0.15, which was not enough to pay school fees (HH-027, Male).

4.6.3 Aflatoxin Detection

Results of the grain quality evaluation revealed that 33% of samples contained more than 10 ppb of aflatoxin. Grain contamination levels were generally higher when grain moisture was greater than 14%, as were levels when the grain exhibited visible mould growth.

Critically, during the lean season, KIIs reported that families will often eat aflatoxin contaminated grain instead of selling it, which will have health consequences (such as liver disease and immune effects in children) and not economic loss. A public health worker said, although the warning was issued, the hungry families eat what they can, but some of the worst kernels ended up in the family porridge (KII-Health-01).

The results indicate that there is a high correlation between poor drying and storage practices and the occurrence of aflatoxin contamination. Grain samples that had moisture content above 14% and mould visible were more likely to contain more than the recommended amount of aflatoxin than grain samples that were dried to the recommended moisture content. The proportion of samples above the limit of 10 ppb (33%) is a clear indicator of the food safety concern that farmers families are facing. The findings highlight the need for early harvests, good moisture control, and better storage practices to minimize aflatoxin contamination.

4.6.5 Impact on Household Food Security

For the study, the relationship between post harvest losses and the duration of food insecurity was examined, which is the number of months a household can cover their maize needs through their own production.

Table 4.6.5: Food Security Outcomes by Post Harvest Loss Category

Loss Category	Proportion of Households (%)	Mean Months Food Self Sufficient	Months of Deficit (Need to Purchase)
Low losses (less than 20%)	19	9	3
Moderate losses (20% to 35%)	47	7	5
High losses (more than 35%)	34	5	7

The results show that the relationship between post harvest loss and food security is very clear. Households with low post harvest losses were food sufficient for nine months on average, whereas moderate loss households were food sufficient for 7 months on average and high loss households for 5 months on average. The increase in post harvest losses meant that household members had less time to depend on their own maize harvest. In addition, 68% of high loss households reported high levels of food insecurity during the January-March lean season, whereas 13% of low loss households experienced the same. The results indicate that the potential benefits of minimizing post-harvest losses are great for food availability and food security to households all year round.

A female respondent described the lived experience of food insecurity due to the consumption of the harvested maize by insects and when her children ask her for sadza, she tells them that there is no maize for them to eat, so they go to her neighbors and she feeds them wild vegetables and pumpkins, saying that she knows that her maize was grown, but they are unable to eat it because it was eaten by insects (HH-073, Female).

4.7 Existing Strategies and Recommendations for Loss Reduction

The fourth specific objective is addressed in this section, which aims to analyze existing strategies to mitigate post harvest losses and come up with actionable recommendations in Chingwere Ward. Findings are based on the Household Survey, KIIs, and direct observation.

4.6.7 Existing Loss Reduction Strategies

Table 4.6.7 shows the post harvest loss reduction strategies farmers are using to reduce post harvest losses in Ward 5 and how they perceive them to be.

Table 4.6.7 Existing Loss Reduction Strategies and Perceived Effectiveness

Strategy	Households Using (%)	“Perceived Effectiveness”	Primary Limitations Reported
Sun drying on bare ground	76	2.4	Physical losses, mould risk, weather dependent
Sorting and winnowing before storage	63	3.1	Labour intensive, incomplete pest removal
Chemical grain protectants	48	3.2	Cost, health concerns, improper application

Smoking granary with plant materials	38	2.8	Temporary effect, labour intensive
Storing cobs unshelled	31	2.9	Takes more space, still susceptible
Use of botanicals (neem, tobacco)	23	2.6	Variable effectiveness, labour to prepare
Hermetic bags	14	4.5	Cost, limited availability, lack of awareness

Scale: 1 = not effective, 5 = very effective

Sun drying on bare ground (76%), was the most common strategy with low effectiveness (2.4/5). One in four farmers (48%) used chemical grain protectants, but they tended to be misapplied, farmers often under- or overdosing powder from agro-dealers, and not reapplying them, allowing insects to return (KII-InputSupplier-01). While use of hermetic bags was rated as the most effective strategy (with a mean effectiveness score of 4.5/5), adoption was still low at 14 per cent.

4.6.8 Barriers to the adoption of improved technologies

The research challenged the non-hermetic storage and improved drying adopters to explain the challenges they encountered. The barriers are ranked by frequency of citation in Table 4.6.

Table 4.6.8: Barriers to Adoption of Improved Post Harvest Technologies

Barrier	Households Reporting (%)
Upfront cost too high	82
Technology not available locally	65
Lack of knowledge about the technology	59
Not sure if it will work for my situation	41
Prefer traditional methods	28
Lack of credit or financing options	26

The barriers most commonly reported were upfront cost (82%), limited availability (65%) and lack of knowledge (59%) which are consistent with the Diffusion of Innovations Theory (Rogers, 2003) which predicts hermetic bags to have high relative advantage, low trialability and low observability as barriers to diffusion.

4.7 Farmer Recommended Interventions

Farmers recommended hermetic bags (subsidised/with credit) (87%), demonstration of improved drying using tarpaulins and moisture meters (80%), better access to mechanical shellers (72%), post harvest training (68%), better access to GMB with faster payout (63%), community drying platforms (55%), and rodent proof storage (51%).

One farmer reported that he heard about hermetic bags but never tried to see working them, pointing out that if AGRITEX could show people how they work for 6 months of storage and the bags had no insects, people would believe because seeing is believing (HH-101, Male).

4.7.1 Proposed Recommendations

This study has identified five recommendations that can be implemented.

To create a subsidized hermetic bag distribution programme. Subsidy is the biggest constraint (82%), and if the cost was reduced in half, to USD 1.25 per bag, via farmer groups or cooperatives, the adoption rate could be significantly higher.

Secondly, improve extension support for post-harvest activities. There is currently only 12 per cent of households that are visited monthly by extension workers and little attention is given to post harvest issues. AGRITEX needs to create separate post-harvest training packages, train extension officers in participatory demonstration techniques, and provide resources for demonstration equipment such as moisture meters, hermetic bags and tarpaulins. Third, develop IMSSs in the community. A cooperative managed and owned mechanical sheller with an affordable rental fee could sell 200 - 300 households, as only 4% of households use mechanical shellers, and price discounts could be reduced by reducing broken grain.

Fourth, encourage better drying by using low cost interventions. It is advisable to show alternatives to tarpaulins such as the use of the repurposed tobacco grading sheets, bamboo drying racks and stitched gunny bags as well as tarpaulins as these are not cost prohibitive for many. Fifth, enhance market incentives for quality. The GMB should shorten the time between payment (4-6 weeks) and delivery, give feedback on the quality that is clearly visible and communicated, and make available communication on the price difference before the delivery, which will make it easier to improve quality.

4.8 Chapter Summary

The results from this chapter were based on a sample of 128 households (or 35%) of the 367 maize farming households in Ward 5, Chingwere. The demographic profile revealed that 68% of the household heads were male while 32% were female, the average household size was 5.8 people, maize accounted for 57% of the cultivated area (1.6 hectares on average) and only 12% of the households received extension visits monthly. Total PHL averaged 35%, with storage having the highest hotspot (19%) and drying next (6%) and shelling next (4%). Traditional granaries reported losses of 23%, hermetic bags reported losses of 5% and the main pests were Larger Grain Borer and maize weevil. The average household had an annual loss of 567 kg (USD 160-199) annually. Only 19% of the grain was of Grade A quality; 47% of the grain was in Grade C quality with discounts. 33% of samples were found to be contaminated by aflatoxins and the low loss households were found to be food self-sufficient for 9 months while the high loss households were food auto-sufficient for only 5 months. Hermetic bags were seen to be most effective for loss reduction but were not widely adopted (14 percent adoption) due to cost, availability, and lack of knowledge. The discussion, conclusions and recommendations of the study are presented in the following chapter.

CHAPTER 5: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter explores the major findings in relation to literature and theory, makes conclusions and suggests recommendations. The chapter concludes with findings (Section 5.2), conclusions (Section 5.3), recommendations (Section 5.4), and suggestions for further studies (Section 5.5).

The study adopted a mixed methods approach, specifically the case study approach with smallholder maize growers in Ward 5 (Chingwere) in Mhondoro Ngezi District, focusing on the extent, causes, and impacts of post harvest losses, focusing on 128 maize growers household surveys (35% of all the 367 maize farming households in the ward), 15 key informants (KII) interviews, direct observation, and grain quality assessment of 40 smallholder maize farmers to generate evidence that addresses the gaps identified in the literature.

5.2 Discussion of Findings

5.2.1 Key Actors in the Maize Value Chain

The first goal was to determine the key players in the maize value chain. The nine actors identified included the smallholder farmers in the middle when production reaches the initial marketing stage, which is in line with Mazvimavi (2021) and Jayne et al. (2010) who noted that smallholder farmers play a central but vulnerable role in Zimbabwean maize value chains.

5.2.1.1 Village based traders as critical but problematic actors

In fact, informal traders were reported to have greater influence in controlling the selling of maize in the ward with key informants reporting that they control 60 to 70% of the maize sales, which corresponds with Jayne et al. (2010). The study showed the relationship between traders and farmers as a paradox as traders facilitate immediate payment, farm gate collection and market access, while at the same time contributing to loss as a result of quality discrimination and price opacity, with 82% of the respondents reporting a price differential of 30-50% between the farmer and the traders, confirming weak bargaining power found by Rukuni et al. (2018).

Traders are an asset and a vulnerability from the Sustainable Livelihoods Framework (DFID, 1999) perspective; they provide immediate cash payments for immediate needs and farmers are losing value through traders because of the price discount they charge; this loss of value can be minimised through the strengthening of collective marketing.

5.2.1.2 Gendered division of labour and its implications

The study revealed that women were mainly involved in shelling (68%), drying (77%) and management of stores (59%) activities which affect the losses, whereas men were mainly

involved in transport to the market (79%) and price negotiation (66%) activities which affect economic returns, consistent with the findings of Gitau et al. (2020).

One female respondent said that although she knew that drying out bare-ground would result in loss, she didn't have a tarpaulin to use because her husband, who controlled the funds, was more concerned with fertilising (HH-033, Female). This contradicts the view that household-level interventions will automatically benefit everyone, indicating that post-harvest interventions need to be targeted at women and need to be trained and financially accessible.

5.2.1.3 Limited extension capacity as an institutional constraint

Only 12% of households had visits to them each month; 18% said that the extension did not visit them at all each month, and 32% said the extension did not visit them at all each season. There was limited extension focus on post harvest issues and only 48% reported limited post harvest advice as a constraint, probably because few had received any to assess.

The ratio of farmers to extension agents (about 1200:1) is such that the provision of individualised training is limited, and sometimes extension officers do not get a chance to visit the wards as they are tied up with fuel problems where the post harvest problems emerge only after the harvest is over (KII-AGRITEX-02).

This is not exclusive to Mhondoro Ngezi but is a common problem reported by the World Bank (2022) and Mvumi et al. (2022) indicating that other delivery mechanisms, farmer field schools, lead farmer training, demonstration plots are required, considering the limited resources at AGRITEX. This approach is supported by Stathers et al. (2020) who reported that such programmes reduced storage losses by seven point 2 per cent.

5.2.2 Causes and Hotspots of Post Harvest Losses

The second goal was to examine the causes and hotspots of PHL. Total losses averaged 35% (95% CI: 33% to 37%), with storage the greatest hotspot (19%, 95% CI: 17.5% to 20.5%), followed by drying (6%) and shelling (4%). The figures are higher than the range of 20 to 30% reported in Zimbabwe (Mvumi et al., 2022) and 15 to 25% reported for Sub-Saharan Africa (Affognon et al., 2015) which may be a reflection of the poor condition of traditional granaries in Ward 5.

5.2.2.1 Storage as the primary hotspot: technology matters

The difference between the traditional granaries and hermetic bags were quite significant, as the traditional granaries were linked with significantly higher storage losses than the hermetic bags. The result shows the value of better storage technologies in minimizing post-harvest losses.

High losses are attributed to the structural vulnerabilities reported, including wall gaps (82% of granaries had), poor ventilation (67%) and poor rodent guards (91%) and disrepaired thatch roofs (43%), and as in the case of one farmer's granary in 1995, these vulnerabilities stem from the deterioration of structures that can be as many as 20 years old. The high disparity in the losses indicated that the use of hermetic technologies in storing smallholder farmers' grains can significantly minimize losses in storage due to pests, with Grain Borer and maize weevil being the principal ones.

The main pests were the Larger Grain Borer (69% reported by households) and maize weevil (82% reported by households), with synergistic damage reported by Stathers et al. (2020). Seventy-one percent of the samples had live insects, with an average of 19 count / kg, which is well above acceptable levels for marketed grain (0 count / kg for Grade A, and less than 5 count / kg for Grade B).

5.2.2.2 Pest infestation: Larger Grain Borer and maize weevil as primary agents

The low uptake of hermetic bag use (14%) despite the high relative advantage (78% reduction in losses from 23% to 5%) can be attributed to limited trialability (farmers can't test without buying) and low observability (not many farmers in their neighbourhood use them), which means that demonstration programmes could help accelerate the diffusion of hermetic bags.

5.2.2.3 Drying as the neglected hotspot

The second hotspot was drying losses with an average of 6% which was not as reported as storage losses. Results indicate that 76% of maize was left to dry on bare ground and that there was a high risk of physical losses and mould in the maize. This shows a missed intervention point. The differences among drying methods observed suggest that the level of post-harvest losses is related to drying practices, with the highest losses observed for the bare-ground drying method. Many households (HH-091, Female) find tarpaulins unaffordable because their priority is to purchase fertiliser, which costs about USD 20.

The results on aflatoxin detection (33% of samples above the limit) are similar to the results by Mvumi et al., (2022) who reported that 42% of samples drawn in Zimbabwe exceeded the limit for aflatoxin. The highest incidence of the significant association of drying method to aflatoxin contamination was observed for poorly dried grain with moisture exposure in a chi-square test. Grain dried on bare ground was more susceptible to contamination due to contact with soil and rainwater and overnight dew. The results underscore the need for better drying practices to ensure food quality and safety.

This carries important public health implications because aflatoxin is a known carcinogen, an immune suppressor and children are particularly susceptible to growth stunting and immune dysfunction. When the contaminated grain is consumed at home (87% of households with contaminated grain), health risks are passed on to the most vulnerable members of the household, but not so economic losses.

5.2.2.4 Shelling losses and quality implications

Generally, mechanical shellers yielded lower broken grain and quality deterioration compared to the manual shelling methods, which were stick-and-beater shelling (87% of households). The low uptake of mechanical shellers was due to rental cost (USD 5 to 8 per hour) and distance to the mechanical shellers in Ngezi town, which was 25 km from Ward 5, thus indicating that a community based service could help reduce the costs of the mechanical shellers due to the shared use.

5.2.2.5 The poverty trap mechanism

PHL is a poverty trap, as described by the key informant (KII-NGO-01). The results indicate that generally the higher the losses experienced at the household level, the lower its income level, and that the higher the losses, the lower the capacity of the household to invest in improved post-harvest technologies (households with losses >35% had 4% of them using hermetic bags compared with 28% for the low losses households, and 2% use of tarpaulins compared with 15% for the low losses households) This reflects the Sustainable Livelihoods Framework, where the losses erode the assets and the resilience of the household, and those with high losses have less to sell, less income and less capacity to invest in lessening their losses the next season, which is

why unless there is outside assistance in place to provide access to otherwise unaffordable technologies, these are prone to high losses.

5.2.3 Economic and Qualitative Losses

The third goal was economic and qualitative losses. The loss of average household weight on a seasonal basis (567 kg (SD = 210 kg)) was worth USD 160 at the farm gate and USD 199 at GMB prices respectively (USD 58,720 to USD 73,033 per season at ward level), which was a significant contribution to the local economy and a direct cost of food insecurity to the household.

5.2.3.1 The quality discount penalty

The significant price differences between quality grades (one-way ANOVA) indicate the economic importance of post-harvest handling and storage of grain to improve the quality of the grain.

This has two implications. First, the quality penalty is high, thereby providing good incentive for improvement; however, farmers are still producing lower quality grain due to the constraints identified here, such as lack of drying capability (80%) and inadequate storage (87%), and their limited knowledge of quality (63%), indicating that farmers are producing at best.

Second, the value loss due to the quality discount goes from the farmers to the buyer and is not reflected on physical loss estimates; therefore, the economic losses due to PHL are significantly larger with the inclusion of quality discounts. Refusing to sell Grade C grain below his fertiliser cost and then being unable to pay school fees, as experienced by one farmer (Male, HH-027), is an example of the total market value of an actual grain being lost. When quality discounts are considered, as done by Hodges et al. (2011) and estimated to be 30-50% of the economic impact of PHL, the total impact in Ward 5 could be more than USD 100,000 per year.

5.2.3.2 Food security consequences

The food self-sufficiency for low-loss (under 20%) and high-loss (above 35%) households differed significantly (95% CI: 5 months (95% CI: 4.5 to 5.5) for food self-sufficiency and 9 months (95% CI: 8.5 to 9.5) for severe hunger, showing the importance of post-harvest management in household food security. The resulting seven-month deficit causes high loss households to seek out food at lean season prices (30 to 50% higher), to food assistance, or to

decrease the number of meals consumed. The post-harvest management is very important in the household food security and has been shown to be reflected in the significant differences in food self-sufficiency and severe hunger between the low loss and high loss households. The psychological as well as material effects of post harvest losses are illustrated by one female respondent reporting that by January her granary was almost empty, and she had to inform her children that there was no maize (HH-073, Female).

This is similar to ZimVAC (2024) which shows that losses of 10% resulted in a loss of 1.4 months in food self-sufficiency. A 35% loss escalates to 20% would mean a gain of some two months of self-sufficiency – a humanitarian need as well as an economic one.

5.2.4 Existing Strategies and Recommendations for Loss Reduction

The fourth goal related to current strategies and recommendations. Hermetic bags also scored high (4.5/5, SD = 0.6) but low adoption (14%) as per Diffusion of Innovations Theory (Rogers, 2003), due to cost (82%), limited availability (65%) and lack of knowledge (59%).

5.2.4.1 The subsidy debate

A USD 2.50, 50 kg hermetic bag reduces storage losses from about 23% to 5%, a net saving of USD 2.52 to 3.15 per bag per season, which is higher than the cost of the bag, and pays off in less than one storage season as shown in the cost-benefit study by Tefera et al. (2021). However, farmers do not have access to these benefits unless they have credit or subsidy. A targeted subsidy (e.g., 50% reduction in cost, USD 1.25 per bag) would be economically and socially justified as would the hermetic bag programme in Kenya, which has reached 400 000 households (APHLIS, 2023).

5.2.4.2 Extension reform priorities

Limited extension contact and neglect of post harvest topics suggest need for change but it is not possible to increase contact unless there is a major ratio change. Farmer field schools, lead farmer training and demonstration plots are more cost effective alternatives. Stathers et al. (2020) reported that storage losses decreased by 7.2 percentage points ($t = 3.84$, $p < 0.01$) when farmer field schools were combined with technology demonstration and trial, which is the trialability and observability limitation in Diffusion of Innovations Theory.

5.2.4.3 Low cost drying alternatives

Cost is not an obstacle to improved drying, when it comes to tarpaulins. Low-cost alternatives used are repurposed tobacco grading sheets (about 5%, free to USD 2), raised bamboo drying racks (2%, labour only) and stitched gunny bags (1%, USD 1 to 2), which resulted in drying losses between 3 to 4% compared to 7% for bare-ground drying. These alternatives need to be shown in addition to tarpaulins in order to have alternatives available at different price levels – “one size fits all” interventions are not suitable for smallholders who are different and awareness of alternatives is as important as affordability.

5.3 Conclusions

Based on the findings of the study, it is concluded that post-harvest losses among smallholder maize farmers in Ward 5 are considerably high and exceed the national average. The study concludes that an average of 35% of harvested maize is lost after harvest, meaning that more than one-third of production fails to reach either the market or household consumption. This level of loss represents a significant threat to household livelihoods, food availability, and agricultural productivity within the ward.

The study further concludes that storage is the most critical stage contributing to post-harvest losses. Evidence from the findings shows that storage losses account for 19% of total losses, representing more than half of all post-harvest losses recorded. Households using traditional granaries experienced substantially greater losses than those utilizing hermetic storage technologies. Therefore, it is concluded that improving access to and adoption of improved storage technologies presents a significant opportunity for reducing post-harvest losses among smallholder farmers in Ward 5.

From the empirical evidence gathered, the study concludes that post-harvest losses contribute to a self-reinforcing cycle of poverty. Households experiencing higher losses generally possess fewer financial resources and are less able to invest in improved post-harvest management technologies and practices. The findings also indicate lower adoption of hermetic storage and recommended drying practices among high-loss households. As a result, it is concluded that without targeted interventions and support mechanisms, this cycle of poverty and post-harvest losses is likely to continue.

The findings further demonstrate that the economic impact of post-harvest losses extends beyond the physical quantity of grain lost. The study concludes that quality deterioration results in substantial financial penalties, as only a small proportion of households produced Grade A maize while lower-quality grain attracted significant price discounts. Consequently, the overall economic burden of post-harvest losses is considerably greater than estimates based solely on physical losses.

Based on the results obtained, the study concludes that food security and post-harvest losses are closely interconnected. Households with high post-harvest losses remained food self-sufficient for a significantly shorter period than households with lower losses. In addition, higher levels of hunger were observed among households experiencing substantial losses. It is therefore concluded that reducing post-harvest losses would directly improve household food availability, food security, and overall well-being.

The study also concludes that the adoption of hermetic storage technologies remains constrained by the three key barriers of affordability, availability, and awareness. Although farmers generally perceived these technologies as highly effective, adoption levels remained low due to high initial costs, limited access, and inadequate knowledge. The findings suggest that these barriers can be addressed through appropriate policy support, awareness campaigns, and improved market distribution systems.

Another important conclusion drawn from the study is that gender plays a critical role in post-harvest management. Women undertake most of the activities associated with drying, shelling, and storage management, yet they often face financial limitations and have limited influence in household decision-making processes. The study therefore concludes that interventions aimed at reducing post-harvest losses must incorporate gender-responsive approaches to ensure effectiveness and sustainability.

Finally, the study concludes that existing agricultural extension services are insufficient to effectively address post-harvest management challenges in Ward 5. The low frequency of extension visits indicates a mismatch between extension service delivery and the magnitude of post-harvest losses experienced by farmers. It is therefore concluded that strengthening extension outreach and increasing the emphasis placed on post-harvest management would significantly contribute to reducing losses and improving agricultural outcomes within the study area.

5.4 Recommendations

The following recommendations are made for each of the stakeholders in light of the results and conclusions of this study. All recommendations are tied to specific findings in Chapter 4.

The recommendations to the Government and Policy Makers are as follows:

Invert a pilot programme of subsidised hermetic bags in Ward 5. Based on the high degree of difference between the two types of households in terms of storage losses, even after the fact of using hermetic bags, government should provide a targeted subsidy that would bring down the farmer cost to around USD 1.25 per 50kg bag through the farmer cooperatives and the GMB depot network. After a successful pilot, the Kenya model (reaching 400,000 households, APHLIS, 2023) can be scaled up to district level.

Enhance the capacity of AGRITEX in post harvest extension. Considering the farmer extension ratio of 1 200:1, the Ministry should put into place specific post-harvest training modules, allocate resources for demonstration equipment (moisture meters, hermetic bags, tarpaulins) and create demonstration plots in each ward as well as train officers in participatory procedures with a particular emphasis on farmer field schools and lead farmer training and the resulting improved post harvest management practices and reduced losses reported.

The GMB should consider the following to improve the quality of grain sold to them: Cut down on payment delays (currently 4-6 weeks); give clear feedback on grain quality at the time of delivery; inform the farmers about the price difference before delivery; and think of introducing the village-based buying points to reduce transportation costs if the grain quality is not of Grade A.

Capitalize on rural drying facilities. Government should provide community platforms for maize drying in each village in Ward 5, which are 100 m² and will cost USD 500 to USD 800 per platform, and will benefit 20 to 30 households in each community, as an enduring public good that should be provided for generations to come.

The recommendations for AGRITEX Extension Services:

Change the focus of extension messaging to include post harvest management. Extension officers should dedicate 30% or more of their contact time to post harvest issues as 35% of losses are

after harvesting; and focus on the following topics: Drying techniques, moisture testing, identification of storage pests and hermetic technology, the latter topics to be presented using pictures in Shona for farmers who have only primary school education (42%) and 9% who have no formal education.

Set-up demonstration plots of post harvest technologies. With lack of knowledge (59%) and uncertainty of effectiveness (41%) being significant obstacles, and with trialability and observability being significant factors according to the Diffusion of Innovations Theory, AGRITEX should have demonstration plots on which farmers can see the hermetic bags, better drying methods, and mechanical shelling before they decide to implement them.

Provide gender responsive post-harvest training. The training should be conducted at times and places convenient to women, focus on their main knowledge requirements, and provide access to financial resources like village savings and loan associations, so that women can purchase technologies without depending on the decision making authority and financial means of the household heads.

Development agencies and NGOs are advised to take the following measures:

To encourage farmer cooperatives to buy technology collectively. Development agencies (CARE International, World Vision, Zim Aid) should help cooperatives to obtain hermetic bags, tarpaulins and shellers at bulk prices etc, and promote group based credit system as a means of alleviating the liquidity constraints facing adoption.

Develop community mechanised shelling services. NGOs should encourage the use of cooperative owned shellers with reasonable prices (USD 1 - USD 2 per hour for members, USD 3 - USD 4 per hour for non-members) and 200 – 300 households each; there is a significant difference between broken grain from manual and mechanical shelling (3.7 percentage points; $t(114) = 4.56$; $p < 0.001$) and NGOs should support cooperatives to be able to afford shellers.

Organise aflatoxin awareness and prevention programmes. Since 33% of the samples were found to be contaminated, health risk awareness sessions should accompany the practical training on drying of bare ground, with a specific focus on the fact that mouldy grain should not be consumed, especially by children, and NGOs should integrate the two.

Recommendations for smallholder farmers:

Organize or join farmer groups to act together. Farmers are advised to join farmer groups as this is associated with higher technology adoption; 38% of group members adopted hermetic bags compared to 8% of non-farmers ($\chi^2(1) = 14.2$, $p < 0.001$); farmer groups would enable farmers to bulk purchase, share information, conduct collective marketing and avail credit facility.

Consider alternatives to drying – such as low cost – until infrastructure improvements. As a first step, the farmers should consider the use of the alternatives to tarpaulins, e.g. used tobacco grading sheets, bamboo racks and stitched gunny bags, to reduce the drying losses from 7% for bare ground to 3 to 4%; while waiting to get to the public investment in drying facilities, tarpaulins are still too expensive for many farmers.

Conduct small-scale tests before full scale adoption of hermetic bags. As per Diffusion of Innovations Theory, uncertainty about effectiveness (41%) and lack of knowledge (59%) are significant constraints and farmers are advised to test hermetic bags on one to three bags before full adoption, farmers will see positive returns even in the small-scale testing of hermetic bags due to the payback period of less than one season (Tefera et al., 2021).

5.5 Suggestions for Future Research

This study has provided useful empirical data for the losses that occur in post harvest operations in Ward 5, but there are some areas where further research is needed:

Multi-season, longitudinal study. This study was conducted within one season (2023/24) but losses fluctuate from year to year depending on climate, pests and prices, so a study of 3-5 seasons would provide more solid estimates and allow trend analysis.

To conduct a randomized controlled trial to determine the effectiveness of the intervention. A cluster randomized trial of subsidized hermetic bags and food security impact; loss reduction and cost-effectiveness would be causal evidence.

Health impact assessment of Aflatoxin. Future studies should examine relationships between post-harvest activities and aflatoxin exposure (biomarker) to health outcomes including child growth stunting and immune function, demonstrating a health burden, in addition to food security.

Future studies should focus on the power dynamics between farmers, traders, and the GMB based on value chain governance approaches, as well as the development of collective marketing and price information systems to enhance the farmer's bargaining power.

Gender Study on Intra-household Decision making. Intra-household participatory research on decision-making processes may help to understand how power dynamics influence the adoption of technology, and if direct interventions are more effective than household-level interventions.

Comparative study between wards. A comparative study, stratified by market access, agro-ecology and socio-economic features across wards would highlight what factors are moderating loss levels and intervention effectiveness in the context, which would help to design more targeted interventions.

Cost effectiveness of intervention packages. The comparative analysis of the cost-effectiveness of intervention packages, hermetic bags, training, drying platforms, and combinations (combination) should be done in the future and expressed as cost per kg saved and as cost per additional month of food self-sufficiency.

Adoption dynamics and tracking of diffusion study. Future research should monitor adoption rates after demonstration and subsidy programs have been implemented, as only 14% of farmers have adopted hermetic bags and the Diffusion of Innovations Theory could be used to identify the early or later adopters, the influence of the opinion leaders, and factors that promote or inhibit the diffusion process to guide scaling of hermetic bags.

5.6 Chapter Summary

This chapter has reviewed the major finding of the study in the light of the available literature and theoretical frameworks, concluded the study and provided practical suggestions for various stakeholders. The discussion showed that PHL in Ward 5 average 35% (95% CI: 33% to 37%), with storage the primary hotspot (19%, 95% CI: 17.5% to 20.5%), followed by drying (6%) and shelling (4%). Traditional granaries are associated with 23% losses as against 5% for hermetic bags ($t(126) = 9.84$, $p < 0.001$) and high losses for vulnerable households are sustained by the poverty trap mechanism ($r = -0.62$, $p < 0.001$). Grade C grain receives 47% price discounts ($F(2,125) = 34.2$, $p < 0.001$), and high-loss households are food self-sufficient for only 5 months

versus 9 months for low-loss households ($t(126) = 4.82, p < 0.01$), with 68% experiencing severe hunger versus 13% ($\chi^2(1) = 28.4, p < 0.001$).

The conclusions highlight that the PHL is far too high, action on storage is urgently needed, the poverty trap is self-reinforcing, quantifiable and gender relevant for the design of interventions, hermetic technology is not widely adopted due to high costs (82%), limited availability (65%) and lack of awareness (59%) and extension services need to be reoriented towards post-harvest management. Recommended practices are subsidy for hermetic bag distribution, post-harvest extension and quality market incentive strengthening, drying facilities investment, community mechanical shelling, gender sensitive training and farmer collective action. The chapter ended with eight recommendations for future research: multi-season longitudinal studies, controlled trials of the effectiveness of interventions, health impact assessment of aflatoxin, value chain governance studies, gender and intra-household decision-making studies, comparative ward studies, cost effectiveness analysis, and tracking adoption dynamics. Put together, the evidence makes it clear that the PHL situation is a crisis that needs to be addressed urgently, but the solutions are available and effective (PHL losses reduced by 78%, $p < 0.001$) and are achievable, if the necessary political will and resources are available. A humanitarian as well as an economic goal, reducing the level of PHL from 35% to 20% would lead to a two-month increase in food self-sufficiency and a decrease in severe hunger cases among high-loss households from 68% to 31%.

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APPENDICES

APPENDIX A: HOUSEHOLD SURVEY QUESTIONNAIRE

Assessment of Post-Harvest Loss in Maize Value Chain in Ward 5 (Chingwere)

Instructions: Please answer the following questions as accurately as possible. The information provided will be treated with utmost confidentiality and is solely for academic purposes.

Section A: Demographic and Socio-Economic Information

Gender of respondent: ☐ Male ☐ Female

Age: _____ years

Marital Status: ☐ Single ☐ Married ☐ Divorced ☐ Widowed

Household size: _____ members

Education level: ☐ None ☐ Primary ☐ Secondary ☐ Tertiary

Main source of income: ☐ Farming ☐ Remittances ☐ Formal employment ☐ Informal trade

Approximate monthly household income (USD): _____

Section B: Maize Production and Harvest Details

8. Maize variety grown in the last season: ☐ SC513 ☐ SC637 ☐ Other (Specify) _____

9. Area under maize cultivation (hectares): _____

10. Total maize harvested in the last season (estimate in kgs or bags): _____

11. Was the harvest sufficient for household consumption? ☐ Yes ☐ No

12. If no, for how many months did the harvest last? _____ months

Section C: Post-Harvest Handling Practices and Losses

13. How do you dry your maize? ☐ On bare ground ☐ On tarpaulins ☐ On raised platforms ☐ Other
14. Who is primarily responsible for drying the maize? ☐ Men ☐ Women ☐ Children ☐ Joint
15. What method do you use for shelling? ☐ Manual (stick/beater) ☐ Mechanical sheller
16. Who is primarily responsible for shelling? ☐ Men ☐ Women ☐ Children ☐ Joint
17. Where do you store your maize? ☐ Traditional granary (Dura) ☐ Hermetic bags ☐ Polypropylene bags in house ☐ Other
18. Who is primarily responsible for storage management? ☐ Men ☐ Women ☐ Joint
19. How long do you typically store your maize? _____ months
20. What pests affect your stored maize? ☐ Larger Grain Borer ☐ Maize weevil ☐ Rodents ☐ Mould ☐ None

Section D: Quantifying Losses and Quality

21. Estimate the percentage of maize lost during DRYING: _____%
22. Estimate the percentage of maize lost during SHELLING: _____%
23. Estimate the percentage of maize lost during STORAGE: _____%
24. Have you ever experienced grain rejection or price discounting at the market/GMB? ☐ Yes ☐ No
25. If yes, what was the reason? ☐ High moisture ☐ Insect damage ☐ Broken grain ☐ Foreign matter
26. What grade was your maize the last time you sold? ☐ Grade A ☐ Grade B ☐ Grade C
27. Have you heard of aflatoxins? ☐ Yes ☐ No

Section E: Mitigation Strategies and Technology Adoption

28. Are you aware of hermetic storage bags (e.g., PICS, GrainPro)? ☐ Yes ☐ No
29. Do you currently use hermetic bags? ☐ Yes ☐ No

30. If NO, what prevents you from using them? ☐ High cost ☐ Not available locally ☐ Lack of knowledge ☐ Other

31. How often does AGRITEX extension officer visit you? ☐ Weekly ☐ Monthly ☐ Rarely ☐ Never

32. Do you receive training on post-harvest management? ☐ Yes ☐ No

Thank you for your time and cooperation!

APPENDIX B: KEY INFORMANT INTERVIEW GUIDE

Instructions for Interviewer: This guide is for Key Informant Interviews (Extension Officers, Village Heads, Traders, NGO Representatives). Use open-ended probes to get detailed responses.

1. Introduction and Roles

Can you briefly describe your role in the maize value chain in Ward 5 (Chingwere)?

Who do you consider the most important actors in the local maize value chain, and why?

How would you describe the coordination between farmers, traders, and extension services in this ward?

2. Causes and Hotspots of Post-Harvest Losses

In your experience, at what stage (drying, shelling, storage, transport) do farmers in Chingwere lose the most maize?

What are the primary causes of storage losses in this ward? (Probe: LGB, weevils, rodents, moisture)

How much of an issue is grain quality (for example, aflatoxin, broken grain) compared to physical quantity loss?

How does the drying and shelling method used by farmers impact their post-harvest losses?

3. Economic and Qualitative Impacts

How do post-harvest losses affect the household food security of farmers in this ward?

What is the economic impact of quality downgrading (for instance, selling Grade C instead of Grade A) on farmers' incomes?

Have you observed a link between post-harvest losses and poverty in this community? (Probe: poverty trap mechanism)

4. Existing Strategies and Recommendations

What post-harvest technologies (for example, hermetic bags, mechanical shellers) are currently being promoted in the ward?

What are the main barriers preventing farmers from adopting these technologies? (Probe: cost, availability, knowledge, gender)

How effective are the current AGRITEX extension services in addressing post-harvest management?

What specific interventions or policies would you recommend to significantly reduce post-harvest losses in Ward 5?

Are there specific gender dynamics that need to be addressed in post-harvest interventions? (Probe: women's roles vs. decision-making power)

APPENDIX C: INFORMED CONSENT FORM

Bindura University of Science Education

Faculty of Agricultural Sciences and Environmental Sciences

Title of Study: Assessment of post-harvest loss in maize value chain in Ward 5 (Chingwere), Mhondoro-Ngezi District.

Researcher: Mawoko Ishmael (Student Number: B224734B)

Purpose of the Study:

You are being invited to take part in a research study investigating the extent, causes, and impacts of post-harvest losses in maize. The goal is to find ways to help farmers reduce losses and improve food security and income.

Procedures: If you agree to participate, you will be asked to complete a questionnaire / participate in an interview. This will take approximately 20-30 minutes of your time.

Risks and Benefits: There are no physical risks to participating. Your answers will help create better policies and extension services for farmers in Chingwere.

Confidentiality: Your responses will remain strictly confidential. Your name will not be used in the final report, and no one will be able to identify you from the results.

Voluntary Participation: Your participation is completely voluntary. You may choose not to answer any question or withdraw from the study at any time without any penalty.

Contact Information: If you have any questions about this study, please contact the researcher, Mawoko Ishmael, at mawokoishmaelquinton@gmail.com / <https://wa.me/263783542504>

STATEMENT OF CONSENT

I have read and understood the above information. I voluntarily agree to participate in this study.

Participant's Signature (or Thumbprint): _____ Date: _____

Researcher's Signature: _____ Date: _____

