

**Grain Post-Harvest Losses and their Effect on Food Security: A Case Study of GMB
Storage Facilities in Zimbabwe**

**A dissertation submitted in partial fulfilment of the requirements for the Master of
Science Degree in Food Security and Sustainable Agricultural
Policy**

Bindura University of Science Education



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DECLARATION

I hereby declare that the research project entitled “**Grain Post-Harvest Losses and Their Effect on Food Security: A Case Study of GMB Storage Facilities in Zimbabwe**” submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of **Dr. L. Musemwa** and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agricultural Policy. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree or diploma.

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DEDICATION

I dedicate this dissertation to God Almighty for His grace, wisdom, strength, and guidance throughout the course of this study.

I also dedicate this work to my family for their unwavering support, encouragement, patience, and sacrifices during my academic journey. Your love and belief in me gave me the strength to persevere through every challenge.

Special dedication goes to all professionals working in grain storage, food security, and post-harvest management in Zimbabwe, whose efforts continue to contribute toward strengthening national food security and improving the livelihoods of communities.

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ABSTRACT

Post-harvest losses continue to be a major challenge to food security, grain quality and management of the strategic grain reserve in Zimbabwe. The GMB plays an important role in maintaining national grain reserves. However, storage related losses of Maize and selected traditional grains continue to compromise grain availability and economic efficiency. The study assessed the extent, causes and economic effects of post-harvest losses in selected GMB warehouses in Zimbabwe. The study was guided by four objectives namely to quantify quantitative post harvest losses in maize and selected traditional grains, to assess qualitative losses including infestation by insects, moisture deviation, broken percentage and aflatoxin contamination, to estimate economic costs associated with post-harvest losses and to assess the implications of storage losses on national food security and strategic grain reserve adequacy . A descriptive cross-sectional census design was adopted targeting all the 89 GMB depots across agro-ecological regions of Zimbabwe. Data were collected via structured online interviews with quality control personnel and by reviewing institutional records of grain storage. A total of 75 depots took part in the study, representing a response rate of 84.3%. For data analysis, descriptive statistics techniques such as frequencies, percentages, tables and a comparative analysis between the storage systems and agro-ecological regions were used. The results showed that maize had higher quantitative storage losses than traditional grains and many depots reported maize losses of 6-10%. The major cause of grain loss was insect infestation followed by moisture damage and inadequate handling. Depots in hotter agro-ecological regions had higher insect-related losses while facilities in humid regions had more moisture-related deterioration and aflatoxin risk. Silo complexes had less losses than storage facilities in warehouses. The study also revealed that post-harvest losses incurred significant economic costs due to decrease in quantity of grain, quality degradation, contamination and rejection of grain and increase storage management costs. Losses in storage also reduced the availability of grain in the strategic grain reserve system in Zimbabwe and contributed to food shortages during drought and deficit periods. The study concludes that post-harvest losses within GMB facilities are a serious threat to national food security and grain reserve efficiency in Zimbabwe. The study recommends upgrading of storage infrastructure, strengthening of pest and moisture management systems, adoption of climate-responsive storage technologies and improvement of environmental monitoring to reduce losses associated with storage.

Keywords: Post-harvest losses, Corn, Traditional grains, Grain storage, Food security

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation Meaning

FAO	Food and Agriculture Organization
GMB	Grain Marketing Board
GIS	Geographic Information System
HACCP	Hazard Analysis Critical Control Point
ICT	Information and Communication Technology
IPM	Integrated Pest Management
PHL	Post-Harvest Losses
PPE	Personal Protective Equipment
SADC	Southern African Development Community
SPSS	Statistical Package for the Social Sciences
USAID	United States Agency for International Development
WFP	World Food Programme
WHO	World Health Organization
ZIMSTAT	Zimbabwe National Statistics Agency

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

Food security is a major challenge in Zimbabwe and sub-Saharan Africa where agricultural systems are increasingly affected by climate variability, economic challenges and post-harvest inefficiencies. Increasing agricultural production remains an important objective, but reducing post-harvest losses is an equally important strategy to increase the availability of food and strengthen national grain reserves. Post-harvest losses occur in stored grain, reducing the quantity and quality of the grain and thus affecting food supply, market value and household nutrition. Understanding the extent, drivers and economic impacts of post-harvest losses of maize and traditional grains is critical for improving grain storage systems and enhancing national resilience to food shortages and climate shocks. Chapter 1. Background of the study Problem statement Research objectives Research questions Hypotheses Conceptual framework Significance of the study Scope and limitations of the research

1.2 Background of the Study

Post-harvest losses (PHL) have increasingly been recognised as a major cause of food insecurity in developing countries. Food loss is defined by the Food and Agriculture Organization (FAO, 2014) as a reduction in the quantity or quality of food that occurs along the supply chain up to the point of retail consumption. It is estimated that 10-30% of total harvested production is lost in sub-Saharan Africa (Affognon et al., 2015). These losses represent not only wasted food but also wasted land, water, labour and financial resources.

In many African countries, most of PHL occurs during storage because of poor infrastructure, high moisture content at intake, infestation by pests, poor aeration and weak monitoring systems (Kumar & Kalita, 2017). The climate change further increases storage risks by increasing temperatures and unpredictable rainfall that promote insect proliferation and fungal growth (Mavhura et al., 2020). These environmental stresses are added to the structural inefficiencies already present in grain storage systems.

In Zimbabwe, maize is the main staple crop, accounting for over 65% of total cereal production and contributing over half of the daily caloric intake for most households (ZIMSTAT, 2023). However, national maize production has been highly volatile, falling

from about 2.7 million tonnes in 2017/18 to 1.5 million tonnes in 2019/20 due to drought and input constraints (FAO/WFP, 2021). In this context, the reduction of post-harvest losses is as important as the increase in production.

The Grain Marketing Board (GMB), set up to administer Zimbabwe's strategic grain reserves, runs 12 main depots, 84 satellite depots and 12 silo complexes across the country. Its mandate is to buy, store and safeguard grain to ensure a stable national food supply during lean seasons. However, parliamentary reports have shown that losses in storage in some facilities average between 7% and 12%, far above the internationally acceptable benchmark of approximately 2% (Parliamentary Portfolio Committee, 2021). Other challenges identified through internal assessments include delayed fumigation, sub-optimal aeration, ageing silo infrastructure and inconsistent moisture enforcement at intake.

The qualitative deterioration is no less a challenge besides the quantitative losses. Aflatoxin contamination is a major public health problem in warm and humid provinces such as Manicaland and Mashonaland Central and is associated with liver cancer and childhood stunting (Williams et al, 2004). Grain that does not meet safety or quality standards is also rejected in export and milling markets, leading to further economic losses.

Although modernisation efforts have been undertaken, including installing temperature monitoring systems at selected facilities between 2018 and 2020, comprehensive facility-level empirical data to quantify the magnitude of both quantitative and qualitative losses within GMB storage systems is limited. The absence of evidence hampers informed decision-making, strategic investment planning and effective policy intervention. Zimbabwe's national food security resilience is dependent on the strengthening of grain storage efficiency, considering the recurring droughts, fiscal constraints and dependence on maize as a staple dietary element. There is thus a need to systematically assess post-harvest losses in GMB facilities to support evidence-based improvements in storage management and policy planning.

1.3 Statement of the Problem

The Grain Marketing Board (GMB) is mandated to maintain Zimbabwe's strategic grain reserve but continues to experience significant post-harvest losses (PHL) during the storage of major staple grains, especially Maize and selected traditional grains such as Sorghum, Millet and Rapoko. Some GMB depots have a storage loss of between 7-12% which is above the international acceptable level of about 2% (Parliamentary Portfolio Committee, 2021).

The large losses reduce the amount of grain available nationwide, drain the strategic grain reserves and increase dependence on expensive grain imports in years when there is a shortfall.

A combination of factors is thought to contribute to these losses including ageing of silo infrastructure, poor warehouse storage conditions, inconsistent enforcement of moisture standards for grain intake, delays in fumigation, poor aeration systems, limited technologies for environmental monitoring, pest infestation and climate variability. Moisture fluctuations, mould growth and insect damage may also lead to quality deterioration of traditional grains such as sorghum, millet and rapoko during storage. But there has been no systematic quantification of these contributing factors at a national level across GMB facilities. Much of the information available is still fragmented, facility-specific, or confined to internal reports that are not publicly comprehensive.

Moreover, there is little empirical evidence on the economic cost of storage-related losses of maize and traditional grains on GMB facilities. In the absence of reliable estimates of quantitative losses, qualitative deterioration and associated monetary losses, policymakers and grain reserve managers would be unable to prioritise investments, upgrade storage infrastructure or implement evidence-based interventions to reduce post-harvest losses.

There is a significant gap in the knowledge required for food security planning in Zimbabwe as there is no comprehensive, facility level, data driven assessment. Ongoing poor monitoring and inadequate response to post-harvest losses of maize, sorghum, millet and rapoko will continue to degrade strategic grain reserves, undermine grain quality and safety and weaken the country's resilience to climate shocks and food shortages. Therefore, there is an urgent need to quantify the extent, determinants and economic implications of post-harvest losses of maize and selected traditional grains in Grain Marketing Board storage facilities in Zimbabwe.

1.4. Aim of study

The study seeks to assess the extent, causes and economic implications of post-harvest losses in selected Grain Marketing Board (GMB) storage facilities in Zimbabwe with a view to informing evidence-based strategies for strengthening national food security.

1.5 Specific Objectives

1. To quantify the percentage of quantitative post-harvest losses in maize and selected traditional grains stored in selected GMB facilities.
2. To assess qualitative losses, including insect damage, moisture deviation, broken grain percentage, and aflatoxin contamination.
3. To estimate the economic cost of post-harvest losses in selected GMB storage facilities.
4. To assess the implications of post-harvest losses on national food security, particularly in relation to strategic grain reserve adequacy and grain availability during deficit seasons.

1.6 Research Questions

The study will address the following research questions:

1. What is the percentage of quantitative post-harvest losses for maize and selected traditional grains stored in selected GMB facilities?
2. What types and levels of qualitative losses (insect damage, moisture deviation, broken grain percentage, and aflatoxin contamination) occur during storage?
3. What is the estimated economic cost of post-harvest losses in selected GMB storage facilities?
4. How do post-harvest losses affect national food security, particularly in terms of strategic grain reserve adequacy and grain availability during deficit periods?

1.7 Conceptual Framework

This study is guided by the post-harvest loss pathway framework adapted from the FAO post-harvest loss model (Hodges et al., 2011), which illustrates how storage-related factors impact food security outcomes. The framework assumes that storage conditions such as moisture content of the intake, length of storage, temperature, relative humidity and exposure to pests and fungi directly determine the extent of grain deterioration during storage. Inadequate control of these conditions increases the risk of quantitative and qualitative losses.

Quantitative losses are loss of weight or volume of grain from shrinkage, spillage, pest infestation or spoilage. Qualitative losses include the deterioration of grain quality such as insect damage, broken kernels, deviations in moisture, nutrient degradation and

contamination by aflatoxins. These losses diminish the quantity of grain that is both safe and saleable.

The reduced volume and quality of grain reduces the monetary value of stored stocks and may necessitate additional imports, thus leading to economic losses from both quantitative and qualitative losses. Large storage losses therefore dilute the adequacy of the strategic grain reserve, reduce national food availability and increase vulnerability in the drought or deficit seasons.

Thus, the framework sets a causal link in which storage conditions influence post-harvest losses that cause economic costs and in turn influence national food security. This relationship directs the measurement and analysis of post-harvest losses in selected GMB facilities in the study.

1.8 Significance of the Study

This study is significant at the institution, country, economy and policy levels. On the institutional level, the findings will provide empirical evidence to help the Grain Marketing Board (GMB) to identify the magnitude and sources of post-harvest losses in its storage facilities. The study will quantify physical and qualitative losses and will support better storage management, monitoring systems and resource allocation.

At the national level, the study contributes to the strengthening of Zimbabwe's food security by highlighting the impact of storage inefficiencies on the adequacy of strategic grain reserve. Reducing post-harvest losses increases the availability of effective grain without increasing production, increasing resilience during droughts and deficit seasons.

Economically The financial impact of the losses will be estimated to show the financial implications of storage inefficiencies and potential savings from improved practices. Such data can help guide cost-effective investments in storage technologies and infrastructure upgrades.

The study is aligned with Zimbabwe's Food and Nutrition Security Policy and the Sustainable Development Goal (SDG) 2 (Zero Hunger) in terms of policy by providing data-driven insights to inform national food security planning and strategic reserve management.

1.9 Assumptions of the Study

This study is based on the following assumptions:

1. Grain intake and storage records maintained by selected GMB facilities are accurate, complete, and accessible for analysis.
2. Sampled storage facilities are reasonably representative of broader storage conditions within the GMB system.
3. Measurement instruments such as moisture meters, temperature and humidity loggers, and aflatoxin test kits produced reliable and valid readings.
4. Prevailing grain prices used for economic valuation reflect realistic market values during the study period.
5. Storage losses measured during the study season reflect typical operational conditions and are not unusually influenced by extraordinary events.

1.10 Scope and Delimitations

This study investigates post-harvest losses at selected Grain Marketing Board (GMB) storage facilities in Zimbabwe. It includes maize and selected traditional grains stored for at least 60 days in one storage season. The study included both silo complexes and bagged-grain warehouses from a variety of agro-ecological regions to reflect the differences of storage conditions.

The study assesses quantitative losses (weight or volume reduction), qualitative losses (insect damage, broken grain percentage, moisture deviation and aflatoxin contamination) and the economic costs related. It further assesses the effects of these losses on strategic grain reserve adequacy and national food security.

However, the study is limited to storage related losses in GMB facilities and does not cover losses at the farm level, during transportation, processing or retail stages. Does not include private or commercial Miller storage systems. Due to resource constraints not the entire stock will be tested for aflatoxin but selected samples will be tested. Additionally, the study covers only one storage cycle and may not fully capture the interannual climate variability.

1.11 Limitations of the Study

Despite efforts to ensure methodological rigour, several limitations could influence the study. The study was conducted for only one storage season which may not be representative of the variation in post-harvest losses over several years with varying climatic conditions.

Secondly, the extent of available historical storage records may vary between sites, limiting the ability to make longitudinal comparisons.

Third, due to limitations in financial and laboratory capacities, aflatoxin testing will be conducted on selected grain samples and may not allow for full generalisation of contamination levels.

Fourth, measurement errors may arise from equipment malfunction or environmental variability. However, calibration and validation procedures will be adopted to minimise such risks.

Finally, findings from the chosen facilities might not be fully representative of all GMB depots throughout the country; nevertheless, efforts will be made to include facilities from different regions and storage types to enhance representativeness.

1.12 Definition of Key Terms

Post-Harvest Loss (PHL): The loss of grain in quantity or quality between harvest and final consumption, especially in storage.

Quantitative Loss: Loss of weight or volume of grain due to spillage, shrinkage, pest infestation or spoilage.

Loss, qualitative: Deterioration of grain quality including insect damage, broken kernels, nutrient degradation, moisture deviation, or aflatoxin contamination.

Aflatoxin: A poisonous substance produced by some species of fungi , especially *Aspergillus* , that infects stored grain and is highly dangerous to health .

Strategic Grain Reserve: The Government, through the Grain Marketing Board (GMB), maintains national grain stocks to ensure availability of food in times of shortages or emergencies.

Food Security: A condition in which all people have physical and economic access to adequate safe and nutritious food to meet their dietary needs continuously.

Silo Complex: Large-scale grain storage facility comprising vertical storage bins for bulk grain storage.

Grain Warehouse-bagged: A storage facility for grain stored in sacks or bags rather than in bulk silos.

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CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Post-harvest losses (PHL) remain a significant challenge to global food security, especially in developing countries where the lack of storage infrastructure and management practices is often evident. Post-harvest loss is the measurable quantitative and qualitative food loss that occurs between harvest and consumption (FAO, 2019). These losses are of particular significance in staple crops such as maize, wheat and rice that are the major dietary sources of calories for millions of people worldwide.

Post-harvest losses in sub-Saharan Africa have been estimated to be between 20 and 40% of total agricultural production, and constitute a serious threat to food security and economic stability (Affognon et al., 2015). These losses reduce the availability of food, increase prices in the market and affect livelihoods of farmers and food system stakeholders. The Food and Agriculture Organization (FAO) estimates that globally about 1.3 billion tonnes of food are lost or wasted each year, which is about one-third of the total food produced for human consumption (FAO, 2021).

Zimbabwe is heavily dependent on maize as its staple food and maize flour constitutes about 27% of the total calorie intake of the country (ZIMSTAT, 2024). While the government has been working to improve grain storage through institutions such as the Grain Marketing Board (GMB), post-harvest losses continue to occur due to poor storage infrastructure, pest infestations, moisture damage and inadequate handling practices.

This chapter reviews the literature on post-harvest losses and their implications for food security. The review addresses global trends, causes of post-harvest losses, storage technologies, the impact of climate change, and the relationship between post-harvest losses and food security. It also presents the research gap that underpins this study.

2.2 Concept of Post-Harvest Losses

Post-harvest losses are the decrease in quantity or quality of agricultural produce during storage, transportation, processing and marketing after harvest (Gustavsson et al., 2018). Losses may be caused by biological, physical, chemical or environmental factors that impair the usability of food products.

There are two main types of PHL:

2.2.1 Quantitative losses

Quantitative losses refer to the reduction in the amount of food available for consumption. The loss is caused by spillage, pest damage, spoilage or poor storage conditions that lead to the destruction of grains. For instance, stored product insect infestations can lead to significant loss of grain weight (Hodges et al., 2014).

2.2.2 Qualitative losses

Qualitative losses are losses that occur when the nutritional value, safety or market quality of food products is degraded. These include contamination by mycotoxins such as aflatoxin, discolouration, and a reduced germination potential. While the amount of grain may not change, its quality for human consumption may be affected (Affognon et al., 2015). Post-harvest losses therefore impact not only the physical availability of food but also the nutritional quality of diets.

2.3 Global Overview of Post-Harvest Losses

Losses after harvest are a major concern in developed and developing countries around the world. But the magnitude and drivers of these losses vary significantly across regions. In developed countries, most of the food losses occur at the consumer and retail levels, because of overconsumption patterns and inefficient food distribution systems. In contrast, in developing countries, losses during harvesting, storage and transport are higher due to poor infrastructure and lack of access to modern storage technologies (Parfitt et al., 2019). Cereal grains are the biggest source of wasted calories in the global food system. Studies have revealed that 50-60% of cereal grains can be lost during storage in poorly managed systems,

but improved storage technologies can reduce these losses to below 2% (Affognon et al., 2015). Hence, reducing post-harvest losses has been identified as one of the most cost-effective ways of improving food security without increasing agricultural production.

2.4 Post-Harvest Losses in Sub-Saharan Africa

Sub-Saharan Africa has some of the highest post-harvest losses in the world. According to the World Bank, the region loses about USD 4 billion worth of grain every year due to poor storage and post-harvest management practices (World Bank, 2020).

Several factors contribute to these high loss levels including: Limited access to modern storage technologies, Inadequate infrastructure, High levels of pest infestation, Poor transportation systems and Lack of farmer knowledge on post-harvest handling.

Smallholder farmers are particularly vulnerable as they tend to use traditional storage methods such as mud silos, granaries and polypropylene bags which provide inadequate protection against pests and moisture. This has made the reduction of post-harvest losses in Africa a major focus of the United Nations Sustainable Development Goal 2 (Zero Hunger).

2.5 Post-Harvest Losses in Zimbabwe

Zimbabwe's agricultural sector plays a vital role in guaranteeing national food security. Maize is still the dominant staple crop with most households consuming it. However, the country faces great challenges in the area of post-harvest management. It is estimated that maize post-harvest losses in Zimbabwe are between 15% and 17.5%, mainly due to poor storage conditions and pest infestations (Mvumi et al., 2014). In Zimbabwe the Grain Marketing Board (GMB) buys, stores and distributes grain reserves. The organisation has a number of storage facilities around the country, including silos and warehouses, to keep strategic grain reserves.

However, GMB facilities face a number of challenges concerning grain storage which include: Legacy storage infrastructure, Absence of monitoring systems, High moisture content at the inlet, Pest attack and Fumigation and aeration limited. These challenges affect the effectiveness of national grain storage systems and lead to food insecurity.

2.5.1 Post-Harvest Losses in Maize and Traditional grains in Zimbabwe

Maize is the staple crop in Zimbabwe and is an important factor in household food security, livestock feed supply and national strategic grain reserves. Traditional grains such as Sorghum, Millet and Finger millet, apart from maize, are becoming increasingly important,

especially in semi-arid areas for their drought tolerance and resilience to climate variability. These grains are important but are highly susceptible to post-harvest losses during handling, transportation and storage.

Loss in grain systems after harvest occurs through both quantitative and qualitative deterioration. Quantitative losses are related to the physical reduction in grain quantity through spillage, pest infestation, rodents and poor handling practices. Qualitative losses are related to the deterioration in grain quality through moisture damage, mould growth, discolouration, nutrient loss and mycotoxin contamination (FAO, 2019). In sub-Saharan Africa, it is estimated that between 10% and 20% of cereal production is lost after harvest, with a large share of these losses taking place in storage (World Food Programme, 2020).

Maize storage losses remain a major challenge at both household and institutional levels in Zimbabwe. Studies have shown poor storage methods, poor pest control and fluctuating moisture conditions are major contributors to grain degradation. Research on maize storage system revealed that untreated stored maize had high damage by insects and loss of weight during storage and the loss increased with the storage period (Golob, 1991). Other studies have reported that the maize value chain is still faced with increased post-harvest losses due to poor storage infrastructure, inadequate warehousing systems and limited adoption of improved storage technologies (Muzari et al., 2022).

The problem of post-harvest losses is not only with maize. Traditional grains such as sorghum, millet and rapoko are also subject to storage-related losses, but they tend to be more resistant to drought and some storage pests than maize. But, improper post-harvest handling, inadequate drying and long storage under high humidity conditions expose them to fungal contamination, insect infestation and loss of quality. Sorghum grain is susceptible to attack by storage moulds and insect pests if moisture content is not properly controlled during storage (Taylor, 2003).

Storage related losses in Zimbabwe and the greater Southern African region are increased by climate variability. High temperature and humidity are favourable for multiplication of insects and growth of fungi in stored grain. Studies in Southern Africa have found strong links between climate conditions and increased storage losses in cereals, especially maize (Stathers et al., 2023). These results are particularly relevant for Zimbabwe, where climate change is increasing the frequency of droughts and temperature extremes, thereby placing greater pressure on grain storage systems.

Another important concern of grain storage losses is aflatoxin contamination. Aflatoxins are poisonous substances made by a certain type of fungus that grows in hot and wet weather. Contaminated maize and traditional grains are a serious health hazard to man and livestock and reduce marketability of grain. Wild and Gong (2010) showed that bad drying, delayed fumigation and inadequate storage monitoring increase the probability of aflatoxin development in stored grain.

In Zimbabwe, although a few studies have investigated post-harvest losses of smallholder farmers and grain traders, little research has been done on institutional storage systems run by the Grain Marketing Board. Most of the available studies focus on farm level losses or localised storage systems rather than nationwide grain reserve facilities (Chitamba et al., 2022). This leaves a huge information gap in terms of the extent, causes and economic implications of post-harvest losses in Zimbabwe's strategic grain reserve system.

In view of the importance of maize, sorghum, millet and rapoko to food security in Zimbabwe, there is a need for a thorough evaluation of storage related losses in GMB facilities. It is crucial to understand the determinants and magnitude of these losses for better grain storage management, reduction of food waste and enhancement of national food security systems.

2.6 Causes of Grain Storage Losses

Post-harvest losses in grain storage systems are affected by a number of factors including biological, environmental and managerial conditions.

2.6.1 Insect pests

Stored grain insects like maize weevil (*Sitophilus zeamais*) and red flour beetle (*Tribolium castaneum*) cause significant damage during storage. These insects feed on grains, which leads to weight loss, contamination and lower quality.

2.6.2 Moisture content

Moisture content is one of the most important factors affecting storage of grains. Grain with high moisture levels is prone to fungal growth and spoilage. The recommended moisture content for storage of maize is generally less than 13% (FAO, 2020).

2.6.3 Temperature and humidity

Increased temperatures and humidity levels hasten insect reproduction and fungal proliferation. Grain deterioration can be encouraged by inadequate ventilation and aeration in storage facilities.

2.6.4 Poor storage infrastructure

Pests and moisture enter storage facilities through poor maintenance or old storage structures. The risk of grain spoilage is increased by poor sealing and ventilation systems.

2.7 Storage Technologies for Reducing Post-Harvest Losses

Several storage technologies have been developed to reduce post-harvest losses in grains.

2.7.1 Metal silos

Metal silos are airtight storage structures used to protect grains from pests and environmental conditions. These silos are common in commercial storage facilities and are effective in maintaining grain quality.

2.7.2 Hermetic storage systems

Hermetic storage refers to the storage of grain in sealed containers, such as hermetic bags or sealed silos. The lack of oxygen inside these containers results in the death of insects and a reduction of the grain's deterioration. Hermetic storage technologies such as Purdue Improved Crop Storage (PICS) bags are now widely used in Africa and have dramatically reduced grain losses among smallholder farmers (Baoua et al., 2014).

2.7.3 Fumigation

Fumigation is a process of using chemical gases to control insect infestations in stored grains. Good fumigation practice is vital to retain the quality of grain stored in large storage facilities such as GMB depots.

2.7.4 Aeration systems

Aeration systems circulate air through grain in storage to control temperature and moisture levels in the storage facility. This eliminates hotspots which encourage insect infestation and mould growth.

2.8 Aflatoxin Contamination and Food Safety

Poor grain storage has been identified as one of the most serious food safety risks of aflatoxin contamination. Aflatoxins are toxic compounds produced by fungi such as *Aspergillus flavus*, which grow on grains in warm, humid conditions. Chronic exposure to aflatoxin is associated with liver cancer, immune suppression and stunted growth in children (Wild & Gong, 2019). The World Health Organization estimates that billions of people around the world are exposed to aflatoxins through contaminated food. High moisture and temperature conditions in stored maize in Zimbabwe have been reported to lead to contamination with aflatoxin. Effective storage management is therefore critical to protecting public health.

2.9 Climate Change and Post-Harvest Losses

The role of climate change as a factor affecting postharvest losses is increasingly acknowledged. Increasing temperatures and changing rainfall patterns create conducive conditions to pests and fungal growth in stored grains.

Increased risks of mycotoxin contamination and pest outbreaks in southern Africa have been associated with climate variability (Mhlanga et al., 2021). These changes require better storage technologies and better monitoring systems to protect grain reserves.

2.10 Relationship Between Post-Harvest Losses and Food Security

Food security is defined as “the situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 2019).

Post-harvest losses directly influence food security through several pathways:

1. **Reduced food availability:** Losses reduce the total amount of food available for consumption.
2. **Increased food prices:** Reduced supply leads to higher market prices.
3. **Reduced farmer incomes:** Farmers lose potential income due to damaged produce.
4. **Increased dependence on imports:** Countries with high post-harvest losses often rely on food imports to meet demand.

Reducing post-harvest losses therefore plays a critical role in improving national food systems and achieving sustainable development goals.

2.11 Research Gap

A lot of work has been performed on post-harvest losses in Africa, but little has been done on grain storage losses in GMB facilities in Zimbabwe. Most of the existing studies focus on smallholder farm storage systems rather than institutional storage facilities. Moreover, there is little empirical evidence on the impact of storage practices, infrastructure conditions and environmental factors on grain losses in GMB depots. This study therefore attempts to fill this gap by assessing the post-harvest losses in selected GMB storage facilities and their implications on food security in Zimbabwe.

2.12 Summary of the Chapter

This chapter reviewed literature on post-harvest losses and their implications for food security. The review pointed out the extent of post-harvest losses in the world and sub-Saharan Africa, the causes of loss during storage of grains, and the contribution of storage technologies to reducing these losses. The chapter also discussed the relationship between post-harvest losses and food security, highlighting the need to improve storage systems to ensure the availability and safety of food. The following chapter will talk about the research methodology adopted for this study which includes the study design, data collection methods and analytical methods.

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CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter presents the methodology used to investigate the post-harvest losses in the Grain Marketing Board (GMB) storage facilities in Zimbabwe. It elaborates on the research design, the study area, the sampling procedure, the methods of data collection, the techniques of data analysis and the ethical considerations guiding the study.

The methodology was designed to address the objectives of the study, which included quantifying the quantitative and qualitative post-harvest losses, estimating their economic cost and assessing the implications of these losses for national food security. A structured and systematic approach was adopted to ensure that data collected were reliable, valid and relevant to the research problem.

This study used a census approach, including all registered GMB depots, rather than studies that use sampling of a subset of facilities. According to the Grain Marketing Board 2024

report, Zimbabwe has a total of 89 GMB depots in all the provinces countrywide (GMB, 2024). This approach yielded a more complete coverage of institutional grain storage systems and improved the generalisability of the findings.

The study employed both primary and secondary data sources. Primary data collection was through digital and online interviews with the members of the quality control teams at the GMB facilities. Secondary data were collected from GMB records such as grain intake, storage and dispatch reports. Digital data collection methods facilitated efficient data collection across geographically dispersed facilities with minimal logistical constraints.

We combined a census based design with multiple sources of data to comprehensively assess post-harvest losses and their determinants across the national grain storage system in Zimbabwe.

3.2 Description of the Study Area

The study was conducted in all the provinces of Zimbabwe and in Grain Marketing Board (GMB) storage depots countrywide. The ten administrative provinces of Zimbabwe are Harare Province, Bulawayo Province, Manicaland Province, Mashonaland Central Province, Mashonaland East Province, Mashonaland West Province, Masvingo Province, Midlands Province, Matabeleland North Province and Matabeleland South Province. These provinces have different agro-ecological conditions that influence the agricultural production patterns and post-harvest storage results.

Zimbabwe has a mainly tropical climate with marked wet and dry seasons. Rainfall is usually experienced between November and March. The temperature and relative humidity vary from regions. Some provinces have higher temperature and humidity, which are conducive to insect infestation and fungal growth during grain storage. These environmental conditions are known to significantly affect post-harvest losses by enhancing the biological and chemical deterioration process (Kumar & Kalita, 2017).

The Grain Marketing Board has an extensive network of storage facilities throughout the country. The GMB has 89 depots strategically located to support national grain procurement, storage and distribution (GMB, 2024) and these include silo complexes and bagged-grain warehouses. These facilities form the backbone of the strategic grain reserve system in Zimbabwe and are critical in ensuring food availability in times of shortage.

The study focused on maize and selected traditional grains stored in these facilities because these crops are the key staples in Zimbabwe's food system. The inclusion of all provinces and all GMB depots ensured that national scale variations in storage conditions, infrastructure, management practices and environmental factors that affect post-harvest losses were captured.

The study area is nationwide, giving the research a holistic evaluation of the post-harvest losses in the institutional grain storage systems and the findings are representative of the Zimbabwean food security picture.

3.3 Research Design

This study was a descriptive cross-sectional study with a predominantly quantitative approach to determine the extent of post-harvest losses in Grain Marketing Board (GMB) storage facilities in Zimbabwe. The design was appropriate as it allows for the systematic collection and analysis of data from a defined population at one point in time which is appropriate for studies aimed at quantifying outcomes and describing relationships between variables (Creswell, 2014).

The data were collected at one point in time, so a cross-sectional approach was used. The focus was on grain that had been stored for a certain period of time. This allowed the study to evaluate postharvest quantitative and qualitative losses without the need for longitudinal follow-up. In agricultural and food systems research, cross-sectional designs are often used to assess storage conditions, grain quality and loss patterns over time (Hodges et al., 2011).

Unlike traditional case study approaches that focus on a limited number of sites, this study adopted a census design that included all Grain Marketing Board (GMB) depots. According to the Grain Marketing Board 2024 report (GMB, 2024), Zimbabwe has 89 GMB depots. A census approach was used to ensure no sampling bias and the results were representative of all institutional grain storage facilities in the country. Studies based on census data are especially useful when the population is manageable and when complete coverage is needed to support policy relevant findings.

This study used mostly quantitative methods to assess post-harvest losses. Quantitative data were collected from GMB records and structured responses from quality control staff at the facility level. Data collected include quantities of grain intake, storage balances, moisture, insect damage and other measures of grain quality. Quantitative approaches are important in

post-harvest studies because they provide objective and measurable estimates of the magnitude of loss and economic impact (Affognon et al., 2015).

The study also included descriptive survey design components through digital and online interviews with quality control teams of GMB facilities. These interviews provided standardised data on storage practices, pest control measures, monitoring systems and operational challenges. The data collection, based on surveys, enabled efficient coverage of geographically dispersed facilities with consistency in data collection.

The research design was suitable for the objectives of the study since it enabled a comprehensive quantification of post-harvest losses, qualitative deterioration, economic costs and their implications for national food security.

3.4 Sampling Procedure

The sampling procedure for this study was guided by the need to obtain comprehensive and representative data on post-harvest losses across the Grain Marketing Board (GMB) storage depots in Zimbabwe. This study did not rely on sampling of a sub-set of units but rather used a census approach whereby all GMB depots were covered. According to the Grain Marketing Board 2024 report, all the 89 GMB depots in Zimbabwe were included in this study (GMB, 2024).

Using Yamane Formula (1967) $n = N / (1 + N(e^2)) = 89 / (1 + 89(0.05^2)) = 73$ depots

As a result, the sample size of the study was equal to the population size ($n=73$).

However, the use of a census ($N=89$) approach was appropriate because the total number of GMB depots was manageable and the study aimed at generating findings that are fully representative of institutional grain storage systems in Zimbabwe. Studies based on census data eliminate sampling bias and increase the generalisability of the results, especially in studies that aim to inform policy and decisions at the national level (Creswell, 2014).

The study focused on key respondents in quality control personnel in each depot. These people were purposively selected because they are directly responsible for monitoring grain quality, storage conditions and post-harvest management practices. These are moisture level assessment, pest infestation detection, storage condition monitoring, and compliance with storage standards. Hence, they are the most appropriate source of technical information for the study.

As each depot had a member of the quality control team, the study aimed to have one structured response per depot. The ideal size of the respondents was about 89 participants . Other knowledgeable personnel within the same facility were asked for further responses, where possible, to improve data reliability.

Such an approach guaranteed the collection of data from all operational units in the GMB system and at the same time guaranteed the consistency of the type of information collected from the facilities. Thus, the census based sampling procedure enabled the study to holistically assess the post-harvest losses and their determinants and implications on food security across Zimbabwe.

3.5 Data Collection Procedure

The data for this study was obtained through a combination of primary (last season 2025 harvest) and secondary data sources to assess post-harvest losses in Grain Marketing Board (GMB) storage facilities across Zimbabwe. The use of multiple sources of data allowed for triangulation, which in turn enhanced the trustworthiness and validity of the findings (Creswell, 2014).

Primary data was collected through digital and online interviews on quality control personnel of GMB depots. A structured questionnaire was developed and distributed electronically through online platforms such as email and web-based survey tools. The questionnaire was developed to gather standardised information on grain storage conditions, post-harvest management practices and grain quality deterioration indicators, such as moisture content, insect infestation, percentage of broken grain and aflatoxin contamination.

The use of digital data collection methods was appropriate considering the nationwide distribution of GMB depots in all the provinces. Online interviews were conducted to collect data efficiently from geographically spread respondents and to minimise the costs and time constraints related to logistics. Further, digital tools improved the accuracy of data by reducing manual data entry errors and facilitating real-time data capture and storage.

Secondary data were collected from GMB records including grain intake reports, stock balance records, dispatch data, fumigation logs and moisture monitoring reports. These records gave quantitative data on the amount of grain received, stored and dispatched, which was essential for calculating post-harvest losses. In post-harvest studies, storage losses are

often estimated by comparing initial and final stocks using administrative records (Hodges et al., 2011).

The questionnaire was structured and consisted of closed-ended and limited open-ended questions. Quantitative data on storage conditions and grain quality indicators were obtained using closed-ended questions, while open-ended questions allowed respondents to offer additional insights on challenges and management practices impacting grain storage.

To ensure data quality, the questionnaire was pre-tested with a small number of respondents for clarity, relevance and consistency. Feedback from the pre-test was utilised to improve the tool prior to full deployment. Follow-ups were done through email and telephone communication to improve response rates across all GMB depots during data collection;

The data collection procedure was designed to generate complete, consistent and reliable data on post-harvest losses, determinants of these losses and implications for food security within the institutional grain storage system in Zimbabwe.

3.6 Data Analysis Procedure

The data analysis in this study was guided by the research objectives. Descriptive and quantitative analytical techniques were used to analyse post-harvest losses in Grain Marketing Board (GMB) storage facilities in Zimbabwe. Online questionnaires and secondary records data was coded, cleaned and analysed using statistical software like Microsoft Excel and SPSS.

Percentage of post-harvest losses was computed using quantitative data collected from GMB records and structured response to questionnaire. The quantitative loss was determined by comparing the quantity of grain received at intake and the quantity after storage. Percentage loss was calculated by the following standard formula:

$$\text{Post harvest loss (\%)} = [(\text{Quantity received} - \text{Quantity remaining}) / \text{Quantity received}] \times 100$$

This approach is commonly used in post-harvest research to estimate storage losses in grain systems (Hodges et al., 2011).

Qualitative data provided by the respondents was analysed using descriptive statistics, such as frequencies and percentages and thematic analysis. The key variables examined were moisture levels, insect infestation, broken grain percentage and aflatoxin contamination.

These indicators were compared with recommended standards for storage to assess the levels of deterioration of grain quality (Food and Agriculture Organization, 2019).

The economic cost of post-harvest losses was calculated as the product of the quantity of grain lost and the prevailing market price per unit weight. This provided a monetary estimate of the losses suffered in all GMB depots, and allowed the economic impacts to be compared.

The results were interpreted in terms of grain availability, adequacy of strategic grain reserve and potential supply gaps during deficit period to evaluate the implication of post harvest losses on food security. The descriptive analysis was applied to link observed loss patterns to the wider food security outcomes, in line with the approaches used in food systems research (Affognon et al., 2015).

Correlation analysis was employed to examine the relationship between variables (storage conditions, moisture levels and level of loss) and to identify the important factors of post-harvest losses.

3.7 Ethical Considerations

Prior to data collection, ethical approval was received from the relevant institutional review board. Formal permission to conduct the study was also sought and received from the Grain Marketing Board to access institutional data and to engage with personnel at its storage facilities.

Participation by respondents, in particular the quality control teams at GMB depots, was voluntary. Informed consent was obtained electronically prior to participating in the online survey. Respondents were given information on the purpose of the study, nature of their involvement and their right to withdraw from the study at any time without any consequences.

Confidentiality and anonymity were rigorously preserved throughout the study. The online questionnaire did not collect personal identifiers, and responses were recorded in a way that individual participants could not be identified. Data were collected securely in password protected digital systems and access was restricted to the researcher. The digital data collection methods used were in accordance with the ethical standards for online research, ensuring the protection of data and privacy of the participants.

Data from GMB institutional records were used solely for academic purposes and treated with a high degree of confidentiality in order to protect sensitive organisational information.

When appropriate, the study findings were reported in aggregate form to avoid disclosure of specific facility-level performance.

Furthermore, the researcher conducted each phase of the research with honesty, integrity, and transparency. All sources of information were properly acknowledged to avoid plagiarism and results were reported accurately without fabrication, falsification or manipulation .

CHAPTER 4: RESULTS: QUANTITATIVE AND QUALITATIVE POST-HARVEST LOSSES IN MAIZE AND TRADITIONAL GRAINS STORED IN GMB FACILITIES IN ZIMBABWE

Abstract

The threat of post-harvest losses to food security in Zimbabwe, especially in institutional grain storage systems managed by the Grain Marketing Board (GMB), remains high. This study quantitatively and qualitatively assessed post-harvest loss on Maize and selected traditional grains (Sorghum, Millet and Finger millet) in GMB storage facilities in

Zimbabwe. The study quantified storage losses and assessed deterioration of grain quality associated with moisture, insect infestation, broken grain percentage and aflatoxin contamination .

A descriptive cross-sectional census design was adopted and targeted all the GMB depots spread across the agro-ecological zones of Zimbabwe. Data were collected using structured online interviews with quality control personnel and secondary review of grain storage records. A total of 75 depots were successfully included in the study and the response rate was 84.3%.

Results showed that quantitative storage losses of maize were higher than traditional grains especially in depots situated in hotter and drier agro-ecological zones. The highest levels were measured in the facilities located in Natural Regions IV and V. For high rainfall provinces such as Manicaland, there was more severe quality deterioration from moisture and higher aflatoxin risk. The study also showed significant differences in post-harvest losses between the silo and warehouse storage systems.

The results underscore the need to enhance environmental monitoring, improve fumigation practices, and modernise storage infrastructure to reduce post-harvest losses and strengthen the strategic grain reserve system in Zimbabwe.

Keywords:

Post harvest losses; Maize; Traditional grains; Grain storage; Food security

4.1 Introduction

In this chapter, the results related to the first two objectives of the study, namely: 1. Quantification of quantitative post-harvest losses in maize and selected traditional grains stored in GMB facilities. 2. Evaluation of qualitative losses such as moisture deviation, insect damage, percentage of broken grains and aflatoxin contamination. The chapter presents findings from structured online interviews with quality control personnel at GMB depots across Zimbabwe and secondary data on grain storage from institutional records. The results are presented in the form of descriptive statistics, tables and narrative interpretation. In the census study, 75 out of the 89 GMB depots targeted were successfully responded to, a

response rate of 84.3%. The participating depots represented all ten provinces of Zimbabwe and included facilities from different agro-ecological regions. Such wide geographical coverage allowed an assessment of the impact of climatic conditions, e.g. temperature, rainfall, humidity and pest prevalence, on storage-related losses of maize and traditional grains. The results in this chapter are mainly related to the quantitative and qualitative losses of grain observed during the storage season 2025. Differences between storage systems, types of grain and agro-ecological regions are given special attention as these have a large influence on post-harvest deterioration of grain.

4.2 Materials and Methods

4.2.1 Description of Study Area

The study was carried out in GMB depots in the ten provinces of Zimbabwe. A detailed description of the study area is given in Section 3.2.

4.2.2 Research Design

The study adopted a descriptive cross-sectional census design as described in Section 3.3.

4.2.3 Sampling Procedure

A census approach targeting all 89 GMB depots was employed. Detailed sampling procedures are presented in Section 3.4.

4.2.4 Data Collection Procedure

Primary data were gathered through structured online interviews with quality control personnel while secondary data were obtained from institutional grain storage records. The specific procedures are outlined in Section 3.5.

4.2.5 Data Analysis Procedure

Data were analysed using descriptive statistics such as frequencies, percentages, means and comparative analysis of grain losses across agro-ecological regions and storage systems. Detailed analytical procedures are given in Section 3.6.

4.2.6 Challenges Encountered During Data Collection

There were several difficulties in gathering data. The response to the online questionnaire was delayed in some depots because of the difficulties in internet connectivity and the

workload pressure on the quality control personnel. There were also facilities that did not have complete historical records for grain storage, especially for traditional grains. Differences in the record-keeping systems of the depots also affected the consistency of the data. However, to increase the completeness and reliability of the data collected, continuous follow-up and data verification procedures were used.

4.3 Results

4.3.1 Response Rate and Distribution of Participating Depots

A total of 75 depots out of the targeted 89 Grain Marketing Board depots participated in the study giving a response rate of 84.3%. The participating depots were located in different provinces of Zimbabwe. The depots consisted of silo complexes and warehouse-based storage systems.

Table 4.1: Distribution of Participating Depots by Province

Province	Frequency (n)	Percentage (%)
Manicaland	17	22.7
Mashonaland West	12	16.0
Matabeleland South	10	13.3
Matabeleland North	8	10.7
Midlands	7	9.3
Harare	7	9.3
Mashonaland Central	7	9.3
Bulawayo	4	5.3
Masvingo	3	4.0
Total	75	100

As shown in Table 4.1, Manicaland Province had the highest number of participating depots, with 17 (22.7%) depots, followed by Mashonaland West Province with 12 (16.0%) depots and Matabeleland South Province with 10 (13.3%) depots. Masvingo Province recorded the lowest participation with 3 (4.0%) depots. The wide provincial distribution of participating facilities allowed for the assessment of post-harvest losses in different climatic and agro-ecological conditions in Zimbabwe.

4.3.2 Distribution of Storage Facility Types

The study further assessed the types of storage facilities represented by participating depots.

Figure 4.1: Distribution of Storage Facility Types

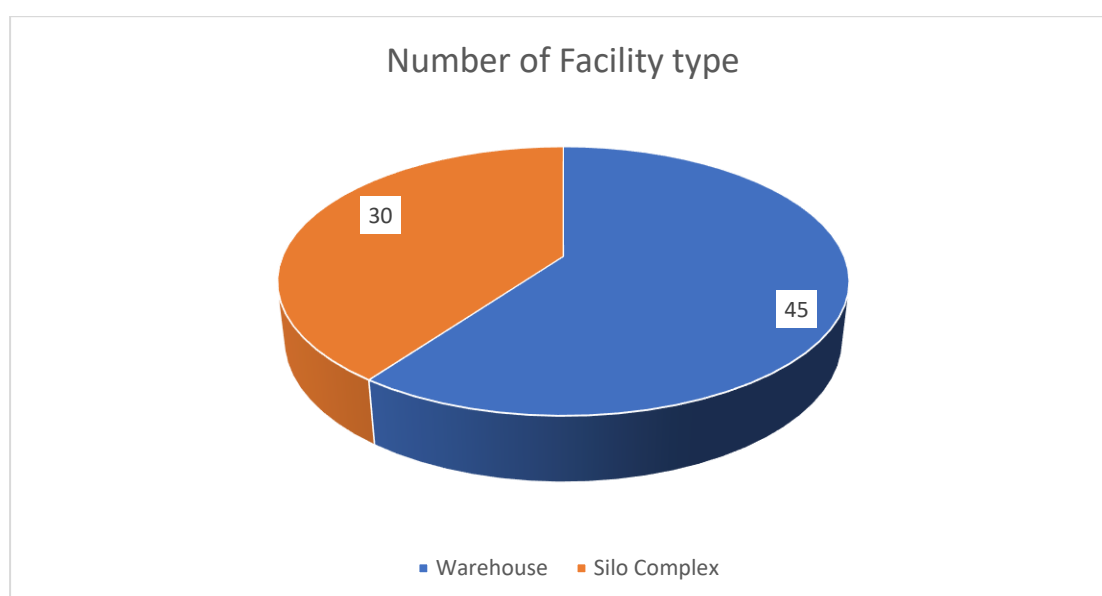


Figure 4.1 presents results that majority of the participating depots were warehouse-based storage facilities, comprising 45 (60.0%) facilities, while silo complexes made up 30 (40.0%). The predominance of warehouse storage systems indicates that a large percentage of the grain stored in Zimbabwe is stored under conditions which may be more prone to variation in moisture, insect infestation and exposure to elements than silo systems.

4.3.3 Quantitative Post-Harvest Losses in Maize

The study assessed quantitative post-harvest losses affecting Maize during the 2025 storage season.

Table 4.3: Estimated Percentage Losses in Stored Maize

Maize Loss Category	Frequency (n)	Percentage (%)
<2%	18	24.0
2–5%	19	25.3
6–10%	21	28.0
>10%	17	22.7
Total	75	100

The results in Table 4.3 indicate that the highest proportion of respondents, 21 (28.0%) reported maize storage losses ranging between 6-10%, while 19 (25.3%) respondents reported losses between 2-5%. In addition, 17 (22.7%) depots experienced >10% losses, whereas only 18 (24.0%) facilities reported <2% losses. These results suggest that a significant proportion of GMB depots suffered maize losses above internationally recommended post-harvest loss thresholds. Losses were higher especially in facilities located in warmer agro-ecological zones where there is more insect activity and deterioration of grain.

4.3.4 Quantitative Post-Harvest Losses in Traditional grains

The study also evaluated quantitative losses affecting traditional grains, including Sorghum, Millet, and Finger millet.

Table 4.4: Estimated Percentage Losses in Stored Traditional grains

Small Grain Loss Category	Frequency (n)	Percentage (%)
<2%	20	26.7
2–5%	27	36.0
6–10%	18	24.0
>10%	10	13.3

Total	75	100
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As shown in Table 4.4, most respondents (27) 36.0% reported small grain losses between 2-5% while 20 (26.7%) facilities recorded losses below 2%. Furthermore, 18 (24.0%) respondents reported losses of between 6–10%, but only 10 (13.3%) depots reported losses of > 10%. Storage losses were generally lower for traditional grains than for maize. This could be attributed to the relatively higher resistance of sorghum, millet and rapoko to storage pests and harsh environmental conditions.

4.3.5 Major Causes of Quantitative Post-Harvest Losses

Respondents identified several causes contributing to quantitative grain losses within GMB facilities.

Table 4.5: Major Causes of Quantitative Post-Harvest Losses

Cause of Loss	Frequency (n)	Percentage (%)
Pest infestation	31	41.3
Moisture damage	18	24.0
Poor handling	13	17.3
Spillage	9	12.0
Rodent damage	4	5.4
Total	75	100

As shown in table 4.5, pest infestation was the major cause of quantitative post-harvest losses as reported by 31 (41.3%) respondents. Of the respondents, 18 (24.0%) reported moisture damage and poor handling practices accounted for 13 (17.3%) of the responses. Losses due to spillage were reported in 9 (12.0%) of the facilities while rodent damage was the least reported causes 4 (5.4%). The dominance of pest infestation as a major cause of grain loss stresses the need to reinforce fumigation and pest monitoring systems in GMB storage facilities, particularly in warmer agro-ecological regions.

4.3.6 Moisture Levels in Stored Grain

The study assessed moisture levels in stored grain as part of qualitative post-harvest losses.

Table 4.6: Typical Moisture Levels in Stored Maize

Moisture Level	Frequency (n)	Percentage (%)
<13%	29	38.7
13–15%	31	41.3
>15%	15	20.0
Total	75	100

From Table 4.6, 31 (41.3%) of the respondents had maize moisture levels ranging from 13–15% while 29 (38.7%) facilities had maize moisture levels below 13%. However, 15 depots (20.0%) recorded moisture levels above 15% which is beyond the recommended standards for grain storage. Higher moisture levels were mainly reported in high-rainfall provinces such as Manicaland Province where high humidity levels increase the risk of mould growth and grain deterioration.

4.3.7 Insect Infestation Levels

The study further assessed levels of insect infestation affecting stored maize.

Table 4.7: Levels of Insect Infestation in Stored Maize

Insect Infestation Level	Frequency (n)	Percentage (%)
None	9	12.0
Low	20	26.7
Moderate	28	37.3
High	18	24.0
Total	75	100

As presented in Table 4.7, moderate insect infestation was the most reported category with 28 (37.3%) depots, followed by low levels of infestation reported by 20 (26.7%) respondents. Eighteen (24.0 %) facilities were highly infested and only 9 (12.0 %) depots reported no

insect infestation. These findings suggest that insect infestation is still a widespread problem in GMB stores. High infestation levels were especially common in warehouse depots in the warmer regions such as Matabeleland South Province and Matabeleland North Province where warmer conditions favour faster insect breeding.

4.4 Discussion

Results of this study show that post-harvest losses on Maize and selected traditional grains remain a major challenge in Grain Marketing Board storage facilities in Zimbabwe. Quantitative and qualitative losses were experienced by the participating depots. However, the extent of losses differed with storage system, climatic condition and agro-ecological region.

The study discovered that maize sustained higher quantitative storage losses compared to traditional grains. This is in agreement with previous studies that showed maize is generally more susceptible to insect infestation and deterioration due to moisture during storage than drought tolerant traditional grains such as Sorghum and Finger millet (FAO, 2019). The lower losses observed in the traditional grains may be due to their hard grain structure and resistance to some storage pests.

Average maize losses in this study were higher than the internationally recommended post-harvest loss thresholds of about 2% especially in warehouse based storage facilities. This indicates that large scale grain losses in storage are still taking place and this lessens the national food pool and the strategic grain reserve system of Zimbabwe. Similar findings have been reported from other Sub-Saharan African countries where storage losses of cereals remain a major driver of food insecurity (Affognon et al., 2015).

Storage infrastructure was identified as an important determinant of post-harvest losses. Depots based in warehouses generally suffered larger losses than silo complexes. This result may be explained by different environmental control systems, aeration efficiency, pest control capacity and grain handling practices. Silo complexes generally have better control of temperature and humidity, limiting pest growth and the proliferation of fungi. But warehouse systems are more sensitive to changes in environmental conditions, especially in regions with high temperature and humidity.

The study also showed clear regional differences in grain losses across the agro-ecological zones of Zimbabwe. Insect infestation and quantitative grain losses were greater in facilities

in Natural Regions IV and V especially in Matabeleland South Province and some areas of Masvingo Province. These findings agree with the literature, which indicates that high temperature promotes insect reproduction and increases metabolic activity in stored grain systems (Kumar & Kalita, 2017). Warm climatic conditions therefore seem to increase the susceptibility of stored maize and traditional grains to deterioration by pests.

In contrast, depots located in areas of high rainfall such as in Manicaland Province, had greater quality deterioration due to moisture and aflatoxin risk. High humidity promotes the growth of fungi and favours the development of mycotoxins in stored grain. The result is in line with previous studies that have related high moisture conditions to increased aflatoxin contamination in cereal storage systems (Wild & Gong, 2010). The occurrence of aflatoxin contamination in some GMB facilities is of major public health concern as contaminated grain may pose health risks to consumers and reduce marketability.

Insect infestation was the primary cause of quantitative loss of grain in the depots surveyed. This finding highlights the need for effective fumigation programs and routine monitoring for pests in institutional grain storage systems. Poor handling practices, spillage and inadequate environmental monitoring are also considered important contributors to storage losses by respondents. These operational challenges may be indicative of resource constraints, ageing infrastructure and variability in storage management practices across depots.

The results also suggest that climatic variability is playing a growing role in the management of Zimbabwe's grain reserve system in the post-harvest period. Climate change in the form of increasing temperatures and irregular rainfall patterns may also increase losses related to storage unless adaptive storage technologies and environmental monitoring systems are enhanced. Therefore, enhancement of grain storage infrastructure and adoption of climate-responsive storage management practices are important to improve resilience of national food security.

In general, the study underscores that the post-harvest losses that affect maize and traditional grains in GMB facilities are a combination of climatic, infrastructural, biological and management factors. Integrated interventions to address these losses are needed to focus on improved storage technologies, strengthened pest management systems, better moisture control, and improved monitoring of grain quality in Zimbabwe's agro-ecological regions.

4.5 Recommendations

The findings of this study give the following recommendations for the reduction of post-harvest losses on Maize and selected traditional grains stored in Grain Marketing Board facilities in Zimbabwe.

The study suggests the modernisation and rehabilitation of grain storage infrastructure, especially warehouse facilities which recorded higher post-harvest losses compared to silo complexes. The investment in better aeration, temperature control and moisture monitoring devices would contribute to mitigating grain spoilage caused by environmental changes.

Building stronger pest management practices is also critical. Insect infestation has been identified as the leading cause of grain losses, hence GMB should strengthen fumigation schedules, upgrade pest surveillance systems and ensure timely execution of pest control measures in all depots. Facilities in warmer agro-ecological zones such as Natural Regions IV and V should receive special attention because higher temperatures increase insect activity and grain deterioration.

The study also recommends routine monitoring of grain moisture content during intake and storage. Keeping moisture levels within the recommended range is important to prevent mould growth and reduce the risk of aflatoxin contamination. Depots in high rainfall areas such as Manicaland Province should enhance drying procedures and environmental monitoring systems to reduce humidity-related quality deterioration.

There is also need for improved practices for grain handling in loading, unloading, transportation and storage operations. Quality control personnel and storage staff should be trained regularly to improve compliance with recommended post-harvest handling standards and reduce avoidable losses due to poor handling and spillage.

The study recommends increasing the use of digital monitoring technologies to assess the storage temperature, humidity and pest activity in real time. Integration of environmental monitoring systems in grain storage operations will allow early identification of storage related risks and timely corrective interventions.

Given the increasing impact of climate variability on storage conditions, climate-responsive grain storage strategies need to be integrated into national food security planning. This includes improving adaptive storage technologies for different agro-ecological zones and boosting preparedness for extreme temperatures and changing rainfall patterns.

Finally, more research is needed on long-term trends in post-harvest losses in Zimbabwe's grain reserve system, including economic modelling of losses under future climate scenarios. Further research on specific storage pests, pathways of mycotoxin contamination and cost effectiveness of alternative storage technologies would also be useful in improving policies on post-harvest management.

4.6 Conclusion

The study examined the quantitative and qualitative post-harvest losses in maize and some selected traditional grains stored in GMB depots in Zimbabwe. The findings indicate that substantial losses of grain are still taking place within institutional storage systems, especially at warehouse based depots and in high temperature and high humidity areas.

Maize was found to have higher quantitative losses than traditional grains. Insect infestation, moisture damage and poor handling practices were found to be major contributors to grain deterioration. Climatic conditions like temperature and rainfall pattern significantly influenced the magnitude and nature of post-harvest losses observed across different agro-ecological regions.

The study also revealed that silo complexes were generally superior to warehouse systems in terms of grain quality preservation and loss reduction. There are still widespread issues with pest management, moisture control and infrastructure limitations in many facilities.

The findings show that post-harvest losses remain a major challenge to food security and adequacy of strategic grain reserves in Zimbabwe. These losses may be reduced by integrating interventions such as modernisation of storage infrastructure, intensified environmental monitoring systems, improved pest management and adoption of climate-responsive grain storage strategies.

4.7 References

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CHAPTER 5: RESULTS: ECONOMIC IMPLICATIONS OF POST-HARVEST LOSSES AND THEIR EFFECTS ON FOOD SECURITY IN ZIMBABWE

Abstract

Post-harvest losses in institutional grain storage systems have major economic and food security implications, especially in countries that rely heavily on strategic grain reserves. The study examined the economic cost of post-harvest losses of maize and traditional grains

stored in Grain Marketing Board (GMB) facilities in Zimbabwe and assessed their implications on national food security.

A descriptive cross-sectional census design was used. The study involved Grain Marketing Board depots across the agro-ecological regions of Zimbabwe. Data were obtained by structured online interviews with quality control personnel and analysis of institutional grain storage records for the 2025 storage season. Descriptive statistical analysis was used to quantify grain losses, estimate the associated market value, determine the effect of storage losses on grain availability, and assess the contribution of post-harvest losses to the national grain deficit.

The findings showed that post-harvest losses resulted in an estimated 6,600 tonnes of grain being lost during storage, comprising 5,420 tonnes of maize and 1,180 tonnes of traditional grains. At the current Grain Marketing Board purchase price of US\$390 per tonne, the total estimated value of the market lost was US\$2,574,000. The study also revealed that post harvest losses led to a 5.08% reduction in grain availability and increased the national grain deficit from 45,000 tonnes after procurement to 51,600 tonnes after storage losses. Overall, post harvest losses amounted to about 12.79% of the total national grain deficit, highlighting their significant contribution to food insecurity. The losses in storage were mainly due to insect infestation, moisture damage, fungal contamination and poor storage infrastructure leading to loss in quantity and quality of grain.

The study concludes that reducing post-harvest losses represents one of the most cost-effective strategies for improving Zimbabwe's food security without increasing agricultural production. Investment in modern storage infrastructure, integrated pest management, digital environmental monitoring systems, and improved grain quality management is recommended to minimise economic losses, strengthen the Strategic Grain Reserve, and enhance national resilience to food shortages.

Keywords: Post-harvest losses, Grain Marketing Board, maize, traditional grains, strategic grain reserve, food security, economic losses, Zimbabwe.

5.1 Introduction

This chapter presents findings related to the third and fourth objectives of the study, namely:

1. Estimation of the economic cost of post-harvest losses affecting maize and selected

traditional grains in GMB storage facilities, 2. Assessment of the implications of post-harvest losses on food security, particularly strategic grain reserve adequacy and grain availability during deficit periods. This chapter presents findings of online interviews with quality control personnel and analysis of institutional data on grain storage obtained from participating depots of the GMB across Zimbabwe. Results are presented using descriptive statistics, tables, and narrative interpretation. Special emphasis is given to the linkages between climatic conditions, grain deterioration, economic losses and food security outcomes in Zimbabwe's different agro-ecological zones. The chapter further examines how quantitative and qualitative grain losses influence the effectiveness of Zimbabwe's strategic grain reserve system and national resilience to food shortages.

5.2 Materials and Methods

5.2.1 Description of Study Area

The study was carried out in Grain Marketing Board depots in all the ten provinces and agro-ecological regions of Zimbabwe. Section 3.2 provides a detailed description of the study area.

5.2.2 Research Design

The study utilised a descriptive cross-sectional census design that targeted all the GMB depots in Zimbabwe as described in Section 3.3.

5.2.3 Sampling Procedure

A census approach was adopted to all 89 GMB depots. Detailed sampling procedures are described in Section 3.4.

5.2.4 Data Collection Procedure

The primary data were collected through structured online interviews with quality control personnel while the secondary data were derived from institutional grain storage records and reports. The detailed procedures are given in Section 3.5.

5.2.5 Data Analysis Procedure

The economic costs of post-harvest losses were calculated using quantitative grain loss data and current grain market values for the 2025 storage season. Data were analysed using descriptive statistics, frequencies, percentages and comparative analysis between agro-ecological regions and storage systems. Section 3.6 describes detailed analytical procedures.

5.2.6 Challenges Encountered During Data Collection

Some depots faced challenges in generating comprehensive financial estimates for grain losses due to issues with record keeping and limited access to detailed economic reports. Standardisation of economic loss estimates was also affected by variation in grain prices across regions and storage time periods. Follow-up communication and verification procedures were used to improve the completeness and reliability of the data despite these challenges.

5.3 Results

5.3.1 Economic Impact of Post-Harvest Losses

The study assessed the economic implications of post-harvest losses affecting Maize and selected traditional grains stored in GMB facilities across Zimbabwe.

Table 5.1: Perceived Economic Impact of Post-Harvest Losses

Economic Impact Level	Frequency (n)	Percentage (%)
Low	12	16.0
Moderate	38	50.7
High	25	33.3
Total	75	100

It can be seen from Table 5.1 that most of the respondents, 38 (50.7%) perceived the economic impact of post harvest losses to be moderate while 25 (33.3%) respondents indicated that the economic impact of post harvest losses is high. 12 (16.0%) respondents rated the economic effects as low. The results show that post-harvest losses lead to significant financial losses for GMB storage operations due to reduction in grain quantity, deterioration in grain quality, refusal of contaminated grain and increase in storage management costs. Facilities situated in warmer agro-ecological areas such as Masvingo Province and Matabeleland South Province usually experienced greater economic losses due to severe insect infestation and faster grain spoilage.

5.3.2 Major Contributors to Economic Losses

The study further assessed the major contributors to economic losses associated with post-harvest grain deterioration.

Table 5.2: Main Contributors to Economic Losses

Contributor to Economic Loss	Frequency (n)	Percentage (%)
Quality deterioration	29	38.7
Quantity loss	24	32.0
Rejection of contaminated grain	14	18.7
Storage inefficiencies	8	10.6
Total	75	100

Table 5.2 presents the main contributor to economic losses was identified as quality deterioration by 29 (38.7%) respondents. Loss of quantity was reported by 24 (32.0%) participants, while rejection of contaminated grain accounted for 14 (18.7%) responses. Storage inefficiencies were the least reported contributor, with only 8 (10.6%) responses. These results indicate that qualitative deterioration of stored grain including moisture damage, insect infestation and aflatoxin contamination significantly reduces the marketability of grain and the financial value of grain stored in GMB systems.

5.3.3 Effect of Post-Harvest Losses on Grain Market Value

The study quantified the financial losses associated with post-harvest grain losses using the prevailing Grain Marketing Board purchase price of US\$390 per tonne.

Table 5.3: Market Value Lost Due to Post-Harvest Grain Losses

Grain Type	Grain Loss (Tonnes)	Market Value (US\$/Tonne)	Total Value Lost (US\$)
Maize	5,420	390	2,113,800
Traditional grains	1,180	390	460,200
Total	6,600	-	2,574,000

The results presented in Table 5.3 show that post-harvest losses led to an estimated loss of US\$2,574,000. The largest share of the losses was maize, which accounted for 5,420 tonnes worth US\$2,113,800, followed by traditional grains with 1,180 tonnes worth US\$460,200. Results indicate that post harvest losses carry significant economic implications for the Grain Marketing Board by reducing marketable grain stocks and loss of revenue. Such financial losses reduce the resources available for future grain purchases and weaken the country's ability to maintain adequate strategic grain reserves.

5.3.4 Effects of Post-Harvest Losses on Grain Availability

The study assessed the quantity of grain lost during storage relative to the total quantity purchased.

Table 5.4: Grain Purchased and Post-Harvest Losses

Grain Type	Total Grain Purchased (Tonnes)	Grain Loss (Tonnes)	Percentage Loss (%)
Maize	110,000	5,420	4.93
Traditional grains	20,000	1,180	5.90
Total	130,000	6,600	5.08

Table 5.4 shows that out of the 130,000 tonnes of grain purchased, 6,600 tonnes were lost in storage, giving an overall post-harvest loss of 5.08%. Traditional grains had a slightly higher percentage loss (5.90%) compared to maize (4.93%). These losses reduced the grain available for national distribution, emergency food assistance and drought relief programmes thereby reducing the effectiveness of Zimbabwe's Strategic Grain Reserve.

5.3.5 Contribution of Post-Harvest Losses to National Food Shortages

The study evaluated how storage losses increased the national grain deficit after procurement.

Table 5.5: Effect of Post-Harvest Losses on National Grain Deficit

Grain Type	Total Grain Requirement (Tonnes)	Deficit After Purchase (Tonnes)	Deficit After Loss (Tonnes)
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Maize	150,000	40,000	45,420
Traditional grains	25,000	5,000	6,180
Total	175,000	45,000	51,600

In Table 5.5 it is shown that despite the grain procurement, Zimbabwe was still in a grain deficit of 45,000 tonnes. The deficit was increased to 51,600 tonnes by post-harvest losses, or an additional shortfall of 6,600 tonnes. This suggests that post-harvest losses significantly aggravate national food shortages by reducing the amount of grain finally available for consumption and distribution. Hence, enhancing the post-harvest management can significantly reduce the national food deficit.

5.3.6 Contribution of Post-Harvest Losses to the National Grain Deficit

The contribution of post-harvest losses to the national grain deficit was calculated using:

$$\text{Contribution (\%)} = (\text{Grain Loss} \div \text{Deficit After Loss}) \times 100$$

Table 5.6: Contribution of Post-Harvest Losses to the National Grain Deficit

Grain Type	Grain Loss (Tonnes)	Deficit After Loss (Tonnes)	Contribution (%)
Maize	5,420	45,420	11.93
Traditional grains	1,180	6,180	19.09
Overall	6,600	51,600	12.79

Post harvest losses were responsible for about 12.79% of the total national grain deficit as shown in table 5.6 Traditional grains had a higher percentage of the deficit (19.09%) compared to maize (11.93%) as they have a higher rate of loss in storage. The results indicate that improving storage losses will significantly increase grain availability, strengthen the

Strategic Grain Reserve of Zimbabwe and reduce national food shortages without increasing grain production.

5.4 Discussion

The findings of this study indicate that post-harvest maize and traditional grains losses have significant economic and food security implications to the Grain Marketing Board (GMB) of Zimbabwe. This study has expanded the scope of previous studies which primarily focused on stakeholder perceptions of the financial value of grain losses, their impacts on grain availability and their contributions to the national grain deficit. The results indicate that the post-harvest losses are detrimental to the quantity and quality of grain for national food security programmes and carry significant financial costs for the Strategic Grain Reserve.

The study estimated a loss of 6,600 tonnes of grain during storage, with 5,420 tonnes of maize and 1,180 tonnes of traditional grains. Based on the current buying price of US\$390 per tonne for GMB, these losses translate into an estimated loss in market value of US\$2,574,000. Maize was the largest proportion of grain stored and thus represented the largest financial loss (US\$2,113,800) while traditional grains lost US\$460,200. These findings confirm that post-harvest losses are both a food security challenge and an economic burden to the grain reserve system of Zimbabwe. Affognon et al. (2015) observed similar results and emphasised that post-harvest losses significantly decrease the profitability and the cost of doing business along cereal value chains in Sub-Saharan Africa.

The analysis also revealed that GMB bought 130,000 tonnes of grain and lost 6,600 tonnes in storage, which means an overall post-harvest loss of 5.08%. This was slightly higher than maize (4.93%), indicating that traditional grains are comparatively more susceptible to storage deterioration under current storage conditions. The percentage losses may seem small, but the absolute amount of grain lost is considerable and represents thousands of tonnes that could otherwise contribute to the national food reserves. These findings are in agreement with previous studies that poor storage conditions, insect infestation, moisture migration and fungal contamination continue to be the major causes of cereal losses in developing countries (Kumar & Kalita, 2017).

The study also showed that post-harvest losses are a huge contributor to Zimbabwe's national grain deficit. The national grain requirement was estimated at 175,000 tonnes but

procurement reduced the deficit to 45,000 tonnes. However, the deficit increased to 51,600 tonnes because of storage losses, so that post-harvest losses alone pushed up the national grain deficit by 6,600 tonnes. These findings emphasise that meeting procurement targets is not enough if large quantities of grain are lost during storage. Consequently, investments in post-harvest management can enhance food availability without necessarily raising agricultural production, a finding that concurs with reports by the FAO (2019).

Post-harvest loss was found to be responsible for about 12.79% of the total national grain deficit. The deficit of traditional grains was comparatively higher (19.09%) than maize (11.93%) because of the higher percentage loss during storage of traditional grains. The results reveal that cutting down on storage losses could greatly decrease national food deficits and enhance the efficiency of the Strategic Grain Reserve in Zimbabwe. One of the most cost-effective ways to improve national food security would be to recover grain that is lost during storage.

The findings also reveal that the observed losses are related to storage challenges including insect infestation, moisture damage, fungal contamination, inadequate environmental monitoring and ageing storage infrastructure. Deterioration affects not only the physical quantities of grain, but also its quality, which results in downgrading, rejection and a decrease in its market value. Hence, the economic losses from post-harvest deterioration are not limited to the value of grain physically lost, but also include a reduction in marketability, higher storage costs and diminished operational efficiency.

In conclusion, the present study shows that post-harvest losses have far-reaching effects on economic performance and national food security. Storage losses reduce the quantity of grain available for distribution and increase the national grain deficit, thereby impairing Zimbabwe's capacity to cope with droughts, humanitarian emergencies and periods of food insecurity. The findings underline the need to invest in post-harvest management as a strategic investment in national food security rather than as just a matter of storage management.

5.5 Recommendations

In light of the findings of this study, the following recommendations are made to reduce post-harvest losses and improve Zimbabwe's Strategic Grain Reserve.

The Grain Marketing Board should focus on investing in the modern grain storage infrastructure, especially in the rehabilitation of ageing warehouse facilities and the proliferation of hermetic and climate-controlled storage technologies. Improved storage conditions would reduce both quantitative and qualitative grain losses and minimise the high financial losses estimated to exceed US\$ 2.5 million in this study.

The study suggests enhancing the integrated pest management programmes by conducting routine fumigation, continuous pest surveillance and better environmental monitoring. As insect infestation remains one of the major causes of storage losses, regular monitoring of grain temperature and moisture content should be standard practice in all GMB depots.

Given the fact that post-harvest losses increased the national grain deficit by 6,600 tonnes, investment in post-harvest management has to be acknowledged as an important national food security intervention. Reducing storage losses would increase the efficiency of public spending on grain reserves and make more grain available without increasing grain production or procurement.

The study also proposes the use of digital storage monitoring systems that can continuously monitor grain temperature, humidity and carbon dioxide concentration. It would also allow real-time monitoring to identify storage problems early and take corrective action before serious deterioration occurs.

Routine grain quality assessment should be enhanced through regular testing for moisture content, insect damage and aflatoxin contamination. Early identification of quality deterioration would reduce grain rejection and preserve market value.

Capacity-building programmes should also be expanded to improve technical skills among warehouse managers, quality assurance personnel and storage operators. Training should focus on best practices in grain handling, storage hygiene, environmental monitoring and integrated pest management.

Finally, further research should evaluate the cost-effectiveness of alternative grain preservation technologies and develop predictive models for estimating post-harvest losses under different climatic conditions. Such studies would support evidence-based planning and improve long-term management of Zimbabwe's Strategic Grain Reserve.

5.6 Conclusion

This study assessed the economic implications of post-harvest losses and their effects on food security within Grain Marketing Board storage facilities in Zimbabwe. According to the study report, about 6,600 tonnes of stored grain were lost due to post-harvest losses, which resulted in an estimated financial loss of US\$2,574,000. Such losses diminished the quantity and quality of grain available for national distribution and undermined the effectiveness of the Zimbabwe's Strategic Grain Reserve.

The study also revealed that the national grain deficit increased from 45,000 tonnes after procurement to 51,600 tonnes after storage losses. Post-harvest losses accounted for about 12.79% of the total grain deficit. These results suggest that improved post-harvest management can significantly increase grain availability without increasing agricultural production or procurement costs.

Results also show that traditional grains experienced marginally higher storage losses in percentage terms than maize, emphasising the importance of grain-specific storage strategies. Storage losses were attributed to insect infestation, moisture damage, fungal contamination and poor storage infrastructure, which all affect the quality and market value of grain.

Overall, the study concludes that reducing post-harvest losses is one of the most practical and cost effective ways of strengthening the national food security system of Zimbabwe. Investments in modern storage infrastructure, digital monitoring technologies, better pest management and improved grain quality control will not only cut financial losses but also enhance the resilience and effectiveness of the country's Strategic Grain Reserve.

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CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter provides a summary, conclusions, policy implications, recommendations and areas for further research arising from the study on post-harvest losses affecting Maize and selected traditional grains stored within Grain Marketing Board facilities in Zimbabwe. The

chapter summarises the main findings from the assessment of quantitative and qualitative grain losses, economic implications and food security effects of storage related deterioration in the agro-ecological regions of Zimbabwe. The study was aimed at assessing the extent, determinants and economic implications of post-harvest losses in GMB storage facilities in order to provide evidence-based recommendations for improving grain preservation and strengthening national food security systems.

6.2 Research Summary

The study was undertaken to assess post-harvest losses of Maize and selected traditional grains namely Sorghum, Millet and Finger millet stored in Grain Marketing Board facilities in Zimbabwe. The study was motivated by growing concerns on grain degradation, economic losses and declining effectiveness of Zimbabwe's strategic grain reserve system emanating from post-harvest storage inefficiencies.

A descriptive cross sectional census design was used. The study was conducted in all the 89 depots of the GMB in the ten provinces and agro-ecological regions of Zimbabwe. Data were obtained through structured online interviews with quality control personnel and from secondary institutional storage records. Of the depots involved in the study, 84.3% of the 75 responded.

The main aim of this study was to quantify the quantitative post-harvest losses incurred by maize and some selected traditional grains. The results showed that storage losses in maize were higher than in traditional grains. Most depots reported maize losses in the 6–10% range, while traditional grains generally experienced lower losses in the 2–5% range. Facilities situated in hotter and drier agro-ecological regions experienced the greatest grain losses as a result of greater insect infestation and faster grain deterioration. These findings are in line with previous studies that have reported that maize is generally more susceptible to storage pests and environmental stress than traditional grains such as sorghum and millet (Kumar & Kalita, 2017; FAO, 2019).

The second objective was to evaluate qualitative post harvest losses like moisture deviation, insect infestation, broken grain percentage and aflatoxin contamination. Moderate to high levels of insect infestation were common in participating depots, especially in warehouse-based facilities in warmer climates, results indicated. Moisture-related deterioration and aflatoxin risks were more prevalent in high-rainfall provinces like Manicaland Province. This is in line with previous studies that have found high humidity and poor storage conditions to

be associated with higher fungal growth and aflatoxin contamination of cereals (Wild & Gong, 2010; Stathers et al., 2023).

The third objective was to estimate the economic cost of post-harvest losses. The study revealed that significant economic costs including reduction in grain quantity, deterioration in grain quality, rejection of contaminated grain and increased storage management costs were incurred due to post-harvest losses. The main economic losses were due to quality deterioration, followed by quantity loss and rejection of contaminated grain. Similar results have been reported in research for Sub-Saharan Africa where the reduction in grain quality has a significant impact on marketability and financial benefits in cereal value chains (Affognon et al., 2015).

The fourth objective was to assess the effect of post-harvest losses on national food security and the adequacy of strategic grain reserves. Most of the respondents observed that the storage losses reduced the availability of grains and played a significant role in the food shortages during drought periods and deficit seasons. Facilities in drought-prone agro-ecological regions emphasised that reducing storage losses could greatly increase the availability of food without necessarily increasing agricultural production. These results are in line with the literature on the need to reduce post-harvest losses as a way of improving food security and making better use of existing food resources (FAO, 2019; World Food Programme, 2020).

The study in general revealed that the post-harvest losses in GMB facilities are caused by several interacting factors such as climate conditions, storage facilities, pest infestation, moisture management and operational practices. Results underscore the need for modernisation of storage systems, improvements in environmental monitoring technologies and climate-sensitive grain preservation strategies in Zimbabwe's diverse agro-ecological zones.

6.3 Conclusions

The study concluded that post-harvest losses of maize and selected traditional grains stored in Grain Marketing Board facilities remain a major challenge to Zimbabwe's food security system. The extent and nature of losses, both quantitative and qualitative, were common in

the participating depots, however, they differed with storage infrastructure, climatic conditions and agro-ecological regions.

The study revealed that maize suffered higher storage losses than the traditional crops like Sorghum, Millet and Finger millet. Storage losses above internationally recommended thresholds were common, especially for those based in warehouses in hotter and drier agro-ecological zones. The main cause of quantitative loss of grain was insect infestation, but moisture damage and poor handling practices also played a significant role in the deterioration of grain. These results align with previous studies that report environmental conditions, pest pressure and poor storage infrastructure as the main drivers of post-harvest losses in cereal systems (Kumar & Kalita, 2017; FAO, 2019; Affognon et al., 2015).

The study highlights that qualitative deterioration is still a major concern in the grain storage system in Zimbabwe. Most of the participating depots had moderate to high levels of insect infestation. The risk of mould growth and aflatoxin contamination was greater in moisture prone areas like the humid areas of Manicaland Province. These findings are consistent with earlier research associating poor moisture management and environmental monitoring with greater grain deterioration and mycotoxin contamination (Wild & Gong, 2010; Stathers et al., 2023).

The study also further revealed that post-harvest losses have economic implications in GMB stores. Losses of grain lead to a decrease in market value, rejection of contaminated grain, and higher storage management costs. Quality degradation was the primary cause of economic losses, underscoring the need for the maintenance of grain quality during storage. Similar observations have been made in other developing countries where grain quality is a major determinant of marketability and economic returns (Affognon et al., 2015).

The study also found that post-harvest losses significantly undermine Zimbabwe's strategic grain reserve system and have a negative effect on national food security. Storage losses reduce grain availability during drought and food deficit periods, increasing vulnerability to food shortages and climate shocks. Facilities in drought-prone areas emphasised the need to reduce losses in storage as a way to improve the availability of food without necessarily increasing agricultural production. These results are in line with earlier studies that have highlighted the importance of post-harvest management in reinforcing food security systems in Sub-Saharan Africa (FAO, 2019; World Food Programme, 2020).

Finally, the study finds that the reduction of post-harvest losses in GMB facilities requires integrated interventions that include modernisation of storage infrastructure, improved pest management systems, moisture monitoring, adoption of environmental monitoring technology, and climate-resilient grain storage strategies. Reducing storage-related losses is critical to improving grain preservation, strengthening strategic grain reserves and enhancing Zimbabwe's resilience to food insecurity and climate variability.

6.4 Policy Implications and Recommendations

This study has important policy implications for grain storage management, national food security planning and strategic grain reserve management in Zimbabwe. The study showed that post-harvest losses on Maize and selected traditional grains significantly reduce the availability of grains, quality of grains and effectiveness of grain marketing board strategic grain reserve system. Hence, coordinated policy, infrastructural, technological and operational interventions are needed to deal with these losses.

The study recommends that the Government of Zimbabwe and GMB should prioritise modernisation and rehabilitation of grain storage infrastructure especially warehouse-based facilities that were associated with higher quantitative and qualitative losses. Investment in improved storage technologies such as improved aeration systems, automated environmental monitoring systems and moisture regulation technologies would help in reducing storage related grain deterioration.

It also recommends improvement of pest control policies and operating systems in GMB storage systems. Insect infestation emerging as the main cause of quantitative losses, there is need for regular fumigation schedules, routine pest surveillance and implementation of integrated pest management strategies across all depots. Facilities in hotter agro-ecological areas such as Matabeleland South Province and Masvingo Province require focused interventions as higher temperatures accelerate multiplication of pests and spoiling of grain.

There is also a need to develop and enforce stricter standards for the management of grain moisture during intake and storage of grain. Depots in humid and high-rainfall areas such as Manicaland Province should improve drying processes and environmental monitoring systems to reduce risks of aflatoxin contamination and mould growth.

The study advocates for increased adoption of digital and climate-responsive storage monitoring technologies that can provide real-time information on grain temperature,

humidity and pest activity. The use of smart storage monitoring systems in institutional grains' management would enhance early detection of storage risks and timely actions before significant deterioration.

Capacity building and ongoing training for quality control personnel and storage staff should also be strengthened. Training programs on grain handling, fumigation practices, moisture management and environmental monitoring would enhance compliance to the recommended post-harvest management standards and minimise avoidable losses from poor operational practices .

The study recommends that post-harvest loss reduction strategies be integrated into the wider agricultural and food security policies of Zimbabwe, from a national food security perspective. Reducing storage losses can significantly improve the availability of grains during drought periods and food deficit seasons, without necessarily increasing agricultural production.

Finally, the study suggests strengthening research and surveillance systems targeting losses in institutional grain storage in Zimbabwe. Continued surveillance of storage performance, pest incidence, climate impact and economic consequences would facilitate evidence-based decision-making and inform future investments in grain storage infrastructure and technologies.

6.5 Areas for Further Research

The study was on post harvest losses of Maize and selected traditional grains stored in Grain Marketing Board facilities in Zimbabwe. The study produced significant findings on quantitative and qualitative losses, economic consequences and food security impacts, but there are various areas that require further research.

Future studies should conduct longitudinal assessments of post-harvest losses over multiple storage seasons to better understand long-term trends and seasonal variations in grain deterioration. Such studies would give a better understanding of the impact of climatic variability and changing environmental conditions on grain storage performance over time.

Further research is also required to quantify the specific economic value of grain losses at the national level using detailed market pricing and cost benefit analysis approaches. This would give a more accurate estimate of the financial burden of post harvest losses in the strategic grain reserve system in Zimbabwe.

Further studies are needed to assess the effectiveness and cost-efficiency of various grain preservation technologies suitable to the agro-ecological conditions of Zimbabwe. Comparative assessments of silo systems, warehouse technologies, hermetic storage methods, and digital systems for environmental monitoring would help policy-makers and storage managers to select appropriate interventions.

Further detailed studies are also necessary on the pathways of aflatoxin contamination and public health risks related to storage-related fungal contamination in maize and traditional grains. Such research would bolster food safety policies and improve grain quality management systems.

Future research should continue to examine the relationship between climate change and post-harvest grain losses, particularly how increasing temperatures, changes in humidity and extreme weather events influence the dynamics of storage pests and grain quality.

Research on institutional capacity, operational efficiency and policy implementation in GMB storage systems would also help to better understand management-related determinants of post-harvest losses.

Finally, there is a need for further research involving advanced statistical and modelling approaches to predict the post-harvest loss risks under different climatic and storage scenarios . Predictive modelling could contribute to development of both early warning systems and climate responsive grain storage strategies for Zimbabwe.

6.6 References

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APPENDIX 1: ONLINE INTERVIEW / QUESTIONNAIRE TOOL

INTRODUCTION TO THE QUESTIONNAIRE

You are invited to participate in a research study. The purpose of this study is to assess the magnitude, causes, and economic implications of post-harvest losses in GMB storage

facilities, and to understand how these losses affect national food security. The questionnaire will take approximately 10–15 minutes to complete. All information provided will be treated with strict confidentiality and will be used solely for academic purposes. No personal identifiers will be collected.

☒ Consent Confirmation

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

SECTION A: RESPONDENT & FACILITY INFORMATION

1. Facility Name: _____
2. Province: _____
3. Type of Storage Facility:
 - ☐ Silo Complex
 - ☐ Warehouse (Bagged Grain)
4. Main Commodity Stored (Tick all applicable)
 - ☐ Maize
 - ☐ Sorghum
 - ☐ Millet
 - ☐ Rapoko (Finger Millet)
5. Your Role:
 - ☐ Quality Control Officer
 - ☐ Depot Manager
 - ☐ Other: _____
6. Years of Experience: _____ years

SECTION B: QUANTITATIVE POST-HARVEST LOSSES (Objective 1)

(Based on the 2025 Harvest Season)

7. What was the average quantity of maize received at your facility during the 2025 storage season?
_____ tonnes
8. What was the estimated quantity of maize remaining after storage?
_____ tonnes
9. What was the average quantity of traditional grains (sorghum, millet, rapoko) received during the 2025 storage season?
_____ tonnes
10. What was the estimated quantity of traditional grains remaining after storage?
_____ tonnes
11. In your estimation, what percentage of maize is lost during storage?
- ☐ <2%
 - ☐ 2–5%
 - ☐ 6–10%
 - ☐ >10%
12. In your estimation, what percentage of traditional grains is lost during storage?
- ☐ <2%
 - ☐ 2–5%
 - ☐ 6–10%
 - ☐ >10%
13. What are the major causes of quantitative post-harvest losses in your facility?
- ☐ Spillage
 - ☐ Pest infestation
 - ☐ Poor handling
 - ☐ Moisture damage
 - ☐ Rodent damage
 - ☐ Other: _____

SECTION C: QUALITATIVE LOSSES (Objective 2)

Moisture Management

14. Is moisture content checked at grain intake?

☐ Yes ☐ No

15. What is the typical moisture level of stored maize?

☐ <13%

☐ 13–15%

☐ >15%

16. What is the typical moisture level of stored traditional grains?

☐ <13%

☐ 13–15%

☐ >15%

Insect Damage

17. How would you rate insect infestation in stored maize?

☐ None

☐ Low

☐ Moderate

☐ High

18. How would you rate insect infestation in stored traditional grains?

☐ None

☐ Low

☐ Moderate

☐ High

Broken Grain Percentage

19. What is the estimated percentage of broken maize grains?

☐ <5%

☐ 5–10%

☐ >10%

20. What is the estimated percentage of broken traditional grains?

☐ <5%

☐ 5–10%

☐ >10%

Aflatoxin Contamination

21. Do you test maize for aflatoxin contamination?

☐ Yes ☐ No

22. Do you test traditional grains for aflatoxin contamination?

☐ Yes ☐ No

23. If yes, how often is aflatoxin testing conducted?

☐ Regularly

☐ Occasionally

☐ Rarely

24. Have you experienced aflatoxin contamination cases in stored grain?

☐ Yes ☐ No

SECTION D: ECONOMIC COST OF LOSSES (Objective 3)

25. How would you rate the economic impact of post-harvest losses in your facility?

☐ Low

☐ Moderate

☐ High

26. Do storage losses significantly reduce the market value of maize and traditional grains?

☐ Yes ☐ No

27. In your opinion, what contributes most to economic loss?

☐ Quantity loss

☐ Quality deterioration

☐ Rejection of grain

☐ Storage inefficiencies

SECTION E: FOOD SECURITY IMPLICATIONS (Objective 4)

28. Do post-harvest losses affect grain availability at your facility?

☐ Yes ☐ No

29. Do these losses contribute to national food shortages?

☐ Yes ☐ No

30. How do storage losses affect strategic grain reserves?

☐ Reduce grain availability

☐ Reduce grain quality

☐ No significant effect

☐ Unsure

SECTION F: STORAGE PRACTICES AND DETERMINANTS

31. Is fumigation conducted regularly in your facility?

☐ Yes ☐ No

32. Are storage conditions monitored (temperature and humidity)?

☐ Yes ☐ No

33. What are the major challenges affecting grain storage in your facility?

SECTION G: OPEN-ENDED INSIGHTS

34. What are the major causes of post-harvest losses affecting maize and traditional grains in your facility?

35. What improvements would you recommend to reduce post-harvest losses in GMB facilities?

APPENDIX: LIST OF DEPOTS

No .	GMB Depot	No .	GMB Depot	No .	GMB Depot	No .	GMB Depot	No .	GMB Depot
1	Harare Silo Complex	19	Muzarabani Depot	37	Nyazura Depot	55	Plumtree Depot	73	Chivhu Depot
2	Bulawayo Silo Complex	20	Centenary Depot	38	Gweru Depot	56	Filabusi Depot	74	Feathersto ne Depot
3	Lions Den Silo Complex	21	Shamva Depot	39	Kwekwe Depot	57	Renkini Depot	75	Headlands Depot
4	Kwekwe Silo Complex	22	Marondera Depot	40	Mvuma Depot	58	Lupanda Depot	76	Penhalong a Depot

5	Mutare Silo Complex	23	Murehwa Depot	41	Shurugwi Depot	59	Esigodini Depot	77	Odzi Depot
6	Banket Silo Complex	24	Mutoko Depot	42	Zvishavan e Depot	60	Insiza Depot	78	Burma Valley Depot
7	Concessio n Silo Complex	25	Kotwa Depot	43	Gokwe Depot	61	Zaka Depot	79	Kariba Depot
8	Chegutu Silo Complex	26	Wedza Depot	44	Masvingo Depot	62	Chivi Depot	80	Binga Depot
9	Gweru Silo Complex	27	Chinhoyi Depot	45	Chiredzi Depot	63	Gutu Depot	81	Victoria Falls Depot
10	Masvingo Silo Complex	28	Chegutu Depot	46	Triangle Depot	64	Mberengwa Depot	82	Umguz Depot
11	Chinhoyi Silo Complex	29	Karoi Depot	47	Mwenezi Depot	65	Chirumhan zu Depot	83	Inyathi Depot
12	Mvurwi Silo Complex	30	Banket Depot	48	Bikita Depot	66	Lower Gweru Depot	84	Jotsholo Depot
13	Aspindale Depot	31	Kadoma Depot	49	Hwange Depot	67	Redcliff Depot	85	Silobela Depot
14	Glen View Depot	32	Hurungwe Depot	50	Lupane Depot	68	Norton Depot	86	Zhombe Depot

15	Mabvuku Depot	33	Mutare Depot	51	Tsholotsho Depot	69	Ruwa Depot	87	Nyika Depot
16	Bindura Depot	34	Rusape Depot	52	Nkayi Depot	70	Epworth Depot	88	Tengwe Depot
17	Guruve Depot	35	Chipinge Depot	53	Gwanda Depot	71	Seke Depot	89	Raffingora Depot
18	Mt Darwin Depot	36	Chimanimani Depot	54	Beitbridge Depot	72	Domboshava Depot		