Economic analysis of determinants of grain storage practices and implications on storage losses and household food security in Makoni and Shamva Districts in Zimbabwe

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DEDICATION

This thesis is dedicated to my family

DECLARATION 1: PLAGIARISM

I, **Teresa Chuma,** declare that:

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As the candidate's supervisors, we agree to the submission of this thesis:

Signed______________________ Date________________________

Dr M. Mudhara (Supervisor)

Signed______________________ Date________________________

Dr J. Govereh (Co-supervisor)

DECLARATION 2: PUBLICATIONS

The following manuscripts (accepted or under review) form part of the research presented in this thesis.

Manuscript 2-Chapter 3

Chuma, T., Mudhara, M & Govereh, J. Factors influencing smallholder farmers' choice of storage technologies in Zimbabwe (*under review*: Food Policy).

Manuscript 3-Chapter 4

Chuma, T., Mudhara, M & Govereh, J. Factors determining smallholder farmers' willingness to pay for a metal silo in Zimbabwe *(under review: Agrekon).*

Manuscript 4-Chapter 5

Chuma, T., Mudhara, M & Govereh, J. The effects of grain storage technologies on maize marketing behaviour of smallholder farmers in Zimbabwe (*under review: Food Policy).*

Manuscript 5-Chapter 6

Chuma, T., Mudhara, M & Govereh, J. The effects of grain storage technologies on the hunger gap among smallholder farmers in Zimbabwe *(under review: Food Security).*

Manuscript 1-Chapter 7

Chuma, T., Mudhara, M & Govereh, J. Storage losses among smallholder farmers and the economic viability of maize stored product protection methods in Zimbabwe *(under revie*w: Agribusiness: an International Journal)

Author contributions

All the papers were conceived by Chuma, T. Data collection, analysis and writing up of the papers were also done by Chuma, T., while Mudhara, M. and Govereh, J. contributed valuable supervision, guidance, insights and comments on every stage of producing the papers.

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ABSTRACT

Despite notable advances in grain storage practices, many smallholder farmers in southern Africa still rely on traditional practices for storing staple crops such as maize. Traditional storage practices do not offer adequate protection of grain against pests such as the Larger Grain Borer (LGB) hence significant post-harvest losses (PHL) are recorded in storage. More so, little attention has been given to the study of the economics of PHL and storage technology, particularly in the smallholder farming areas where issues of food security and poverty are concentrated.

This study meant to compare the economic viability of traditional and improved storage technologies, examine the factors that influence smallholder farmers' choice of storage technologies, analyse determinants of willingness to pay for a metal silo, and determine the effects of storage technologies on household hunger gap and market participation in Zimbabwe. A structured questionnaire was used to collect data from 417 households chosen using the multi-stage sampling method in Makoni and Shamva Districts. Various econometric methods such as cost-benefit analysis, multinomial logit, logit, ordered probit and truncated regression models were used to analyse the data.

Storing maize grain using hermetic technologies was found to be most profitable when compared to untreated and ACTELLIC dust (*pirimiphos-methyl)* treated polypropylene bags. The benefit-cost (B/C) ratios were also greater for hermetic technologies. Comparing the two hermetic technologies, the super grain bags were found to be more profitable than the metal silo. Nevertheless, both technologies were superior to the smallholder farmers' storage technology of treated bags. Sensitivity analysis results, on the other hand, revealed that both hermetic storage technologies are sensitive to reduction in investment period. This is a result of the high investment costs that are associated with the technologies. The results, however, indicated that super grain bags are more suitable for smallholder farmers who are resource limited and cannot invest in a silo since super grain bags have a higher financial return than a metal silo. On the other hand, metal silos are the most suitable and robust storage technology for smallholder farmers who have long-term storage investment plans. It should, however, be noted that to create and keep gas-tight conditions in metal silos or super grain bags is a demanding and expensive task that requires pronounced scientific and technical skills.

Dissemination of the technology should thus encompass farmer and artisan training package on proper handling and management of the hermetic technologies to reap maximum benefits from the inert atmospheres created. Provision of credit may be required to allow farmers to meet the high initial investment costs.

Household head's age, education years, marital status, total grain stored, the value of non-food crops, business and wages income, and access to extension services were found to have a diverse influence on the choice of grain storage technologies. Older households had higher chances of using the insecticide storage technology indicating that farming experience influences the choice of grain storage technologies. Therefore, the government and development agents should target older household heads for promotion and dissemination of storage technologies. Marital status also increased the chance of using the insecticide storage technology suggesting that married household heads are less risk-averse. Therefore, government and storage technology development agents should target married households for dissemination, without marginalizing unmarried household heads. Furthermore, the total grain stored influenced smallholder farmers to use the insecticide storage technology versus the no insecticide technology. Thus, policies that promote agricultural production will enhance the use of improved storage technologies among smallholder farmers. Hence, the government should support agricultural production activities of smallholder farmers. Thus, policies that promote agricultural production will enhance the use of improved storage technologies among smallholder farmers. Hence, the government should support agricultural production activities of smallholder farmers. Households with a higher value of non-food crops showed higher chances of using the insecticide storage technology relative to the no insecticide technology. Hence, development agents and the government should develop programs that support the production of non-food crops in smallholder areas without side-lining maize production. Results showed that better-educated smallholder farmers had higher chances of using the insecticide storage technology. The government should develop adult learning programs in the areas to increase access of farmers to education. However, smallholder farmers with income from business and wage activities showed less likelihood to use the insecticide storage technology. This implies that such smallholder farmers have fewer chances of storing grain hence are more likely not to choose the insecticide storage technology. Although access to extension had a negative influence on the choice of storage technology, it is important that government develops specific extension training programs on storage technology particularly the use of insecticide storage so as to equip farmers with proper storage skills and information.

In terms of farmers' willingness to pay for a metal silo, the results found that the household head's age, marital status, non-food crop quantity, equipment value, vegetable income, storage loss and informal activity participation were the key determinants of willingness to pay for a one-tonne metal silo storage technology in Zimbabwe. The results revealed that married respondents and young farmers are more ready to pay for metal silos than their counterparts. While it is recommended that development agents promoting the metal silo technology should target these households for a sustainable approach, care should be taken not to marginalize their counterparts. All the income variables except equipment value showed a positive influence on WTP for a metal silo. Increasing household's income will help to ease the financial constraints that often impede technology investment among smallholder farmers. Therefore, policies that encourage diversification of agriculture and also provision of credit are recommended in order to increase WTP for a metal silo. The amount of grain lost in storage had a positive influence on farmers' WTP for a metal silo. This suggests that current storage practices are not effective against storage losses and the metal silo can be an alternative effective storage to curb storage losses and hence improve their food security and livelihoods.

The study results revealed that storage practices had significant effects on both maize marketing behaviour and hunger gap of smallholder farmers. The use of insecticide storage increased the chances of farmers becoming net sellers of maize. Using insecticide storage reduces the amount of grain that is lost in storage hence farmers are able to preserve the amount of grain available for consumption and also for sale. This implies that safe storage of maize promotes smallholder farmers' net maize selling behaviour thus reducing poverty and also contributing to improved food security. Investment in safe grain storage technologies is thus a fundamental key policy issue in developing countries and as such government should design storage policies that encourage dissemination and promotion of safe grain storage technologies at the household level. Household head's gender, marital status, quantity harvested, market location, farming systems and district location were other factors that influenced maize marketing decisions of smallholder farmers in Zimbabwe.

Moreover, results showed that the majority of the households experienced hunger gap. On average, households that experienced it had a hunger gap intensity of 4.7 months. This means that food insecurity is an issue of concern among smallholder farmers. Policymakers should come up with effective measures to safeguard lives of people either by boosting production or promoting safe storage of maize grain. Several household socio-economic characteristics such as age, household size, gender, marital status, location, education years, and being an A1 model or old resettlement farmer and no treatment storage significantly influence the occurrence of household hunger gap. Farmers who used no treatment on stored grain had better chances of not incurring hunger gap in the study areas. Hence, there is need to investigate the location-specific characteristics of smallholder farmers. The government may also develop programs targeted to improve post-harvest knowledge and skills of smallholder farmers. Smallholder farmers record significant storage losses which lead to the hunger gap. Protecting grain crops is thus an important step towards ensuring food security. Larger household size increased chances of experiencing hunger gap, which suggests the need to implement effective family planning methods to keep the family sizes small. Development agents should provide effective family planning education and training to farmers in the rural areas. Farmers who had larger sizes of cultivated land showed lower chances of experiencing hunger gap than their counterparts. Therefore increasing smallholder farmers’ access to land will alleviate the problem of hunger gap and food insecurity. Households with a higher level of education had lower chances of incurring hunger gap, therefore, the government should develop adult learning programs to increase literacy levels of households in the area and hence reduce hunger gap occurrence. It was also observed that hunger gap differs by location, farming system, and storage practices. Farmers in Shamva district showed higher chances of experiencing a hunger gap than those in Makoni district, while farmers in the A1 model and old resettlement schemes had better chances of incurring no hunger gap. These farmers have better access to land, and other productive resources thus lower chances of incurring hunger gap. Hence, government supported input schemes should target areas where farmers have less access to inputs so as to improve productivity. On the other hand, the quantity of grain harvested, total grain stored, income from business and wages and land size had a negative effect on hunger gap intensity while hunger gap intensity increased if the household head was married and no insecticide storage technology was used to store maize grain.

To sum up, the study, recommends that government should develop policies that encourage farmers to invest in improved storage technologies such as the hermetic metal silo, and also to provide credit to farmers to enhance adoption and dissemination of new improved storage technologies. The study further recommends that government should develop effective extension programs tailor-made to increase and improve smallholder farmers' post-harvest management knowledge and skills, respectively.

LIST OF ACRONYMS

ANOVA	One-way Analysis of Variance
AGRA	Alliance for a Green Revolution in Africa
AGRITEX	Department of Agriculture, Extension and Technical Services
B-C	Benefit-Cost
CIMMYT	International Maize and Wheat Improvement Center
CBA	Cost-Benefit Analysis
CRD	Completely Randomised Design
DH	Double Hurdle
EA	Enumeration Area
EGSP	Effective Grain Storage Project
EUT	Expected Utility Theory
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FEWSNET	Famine Early Warning Systems Network
IAE	Institute of Agricultural Engineering
IITA	International Institute of Tropical Agriculture
ICF	ICF International Inc
IMR	Inverse Mills Ratio
IRR	Internal Rate of Return
LGB	Larger Grain Borer
MLE	Maximum Likelihood Estimator
MNL	Multinomial Logit
MNP	Multinomial Probit
NGO	Non-Governmental Organizations
NPV	Net Present Value
OCC	Opportunity Cost of Capital
OLS	Ordinary Least Squares
PHL	Post Harvest Loss
SCF	Small Scale Commercial Farmers
SDC	Swedish Development Cooperation
SGB	Super Grain Bags

SSA	Sub-Saharan Africa
UNICEF	United Nations Children's Fund
UZ	University of Zimbabwe
VIF	Variance Inflation Factor
WFP	World Food Programme
ZIMSTAT	Zimbabwe National Statistics Agency
ZimVAC	Zimbabwe Vulnerability Assessment Committee

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CHAPTER 1 INTRODUCTION

1.1 Background to the study

Farmers in southern Africa face many constraints when producing staple food crops and have many challenges in post-harvest grain management (Didier et al., 2013). One of the challenges that farmers face in post-harvest grain management is access to storage technology. This has remained one of the most problematic issues throughout the post-harvest chain with multifaceted repercussions on household food security, incomes and general livelihoods of poor rural farmers.

As a result, many smallholder farmers in southern Africa still rely on traditional storage practices for storing staple grain crops such as maize, despite the notable advances in grain storage practices (Tefera, 2012). These traditional storage practices made from locally available and often cheap materials are prone to pest and rodent attacks (Tefera, 2012). Examples of these traditional storage practices include woven baskets, open platforms, gourds, cribs, thatched rhombus, mud and pole/brick granaries, jute bags, metallic drums, bins, calabashes, earthenware pots and plastic bags (Nyagwaya et al., 2010; Nukeine, 2010; Tefera, 2012; Mvumi et al., 2013).

In general, smallholder farmers use traditional storage structures because they are relatively inexpensive to construct (Adejumo and Raji, 2007; Mhiko et al., 2014). However, with the outbreak of the larger grain borer (LGB), which is capable of damaging a variety of food commodities including wooden objects, drying timber and leather (Rwegasiya et al., 2003), the safe storage of grain in these storage structures is at a risk. Significant storage losses that range between 20% and 30%, are recorded in these traditional storage technologies, with annual losses of about 50% in cereals having been reported (Nukeine, 2010; Tefera and Abass, 2012; World Bank, 2011). Such losses can actually lead to food insecurity at household level.

Additionally, farmers may be forced to sell any surplus grain immediately after harvest when prices are at their lowest, as a strategy to curb the storage losses and partly to meet other financial needs, thereby foregoing future and better incomes from improved maize prices, thus aggravating the household food security situation (Kimenju et al., 2009). Safe storage of maize at the farm level is thus crucial as it directly impacts on poverty alleviation, food and income security of smallholder farmers.

In Zimbabwe, smallholder farmers store their grain in shelled form, packaged in polypropylene bags, jute bags, cotton wool bags in pole and dagga or mud granaries or rooms in houses (FAO, 2010; Mhiko et al., 2014). Maize has to be stored to ensure constant supply throughout the year, yet significant storage losses incur at the farm level. About 70% of the maize smallholder farmers produce, they store on the farm for household food consumption (Nyagwaya et al., 2010; Mvumi et al., 2013; Mhiko et al., 2014).

In order to preserve their maize grain in storage, the farmers use a wide range of stored-product protection methods; which include actellic dust, plant and other botanical products such as ash, and gum tree leaves (Mvumi and Stathers, 2003). The efficacy of these protection methods is dwindling as pests such as the LGB and maize weevils develop resistance to them. Besides this, the use of insecticides is receiving much focus of late due to the rising environmental and farmer health concerns. According to Adejumo et al. (2014) and Hossard et al. (2014), the residual products of insecticides are toxic and their continuous use can lead to environmental pollution and health hazards. Misuse of the insecticides has also resulted in the loss of grain in storage. Nevertheless, maize grain storage remains critical to the achievement of household food security as at least 70% of the population in Zimbabwe directly depends on agriculture for their livelihood (Ministry of Agriculture, 2012).

More so, maize production is seasonal as it mainly relies on rain-fed agriculture. It is widely grown by smallholder farmers who contribute about 50% to the national production (Rukuni et al., 2006; Kapuya et al., 2011). Storage is, therefore, a vital component of the maize value chain in the country where approximately 16% of rural households and almost 1.5million people are food insecure during the peak hunger season between January and March (UNICEF, 2016). According to ZimVAC (2016), 42% of the rural population is food insecure during the hunger season. Food insecurity is persistent in Zimbabwe with at least 12% of the rural population experiencing it over the last five years (WFP, 2014). Maize is stored between August and March and households incur losses during this period (WFP, 2014). Households may go for some months with no maize in stock, due to storage losses. Moreover, the outbreak of storage pests such as the larger grain borer is threatening the household food security situation in Zimbabwe.

Nonetheless, research on the role of storage practices in influencing household hunger gap and its intensity in the country is limited. Hence, it is important to look at smallholder farmers' storage practices and their impact thereof on hunger gap so as to inform new policy that can develop appropriate interventions to mitigate food insecurity.

Little attention has also been paid to the economics of post-harvest losses (PHL) and storage technology in studies on household grain management; in particular, their effect on market participation. On the other hand, advancements in grain storage technologies have resulted in the introduction of more effective hermetic grain storage technologies (de Groote et al., 2013). Hermetic technologies work by creating an inert atmosphere that depletes the supply of oxygen and promotes accumulation of carbon dioxide thus suffocating any living organism particularly pests. No insecticides are applied in these storage technologies. Namely, these are the metal silos and super grain bags. According to Joseph et al. (2012), use of hermetic technologies can lead to better quality grains, less usage of pesticides and hence directly contribute to rural development and poverty reduction.

Hermetic technologies are new in Zimbabwe, and the International Maize and Wheat Improvement Center (CIMMYT), with support from the Swedish Development Cooperation (SDC), introduced the technology on a pilot basis in 2012, targeting two farming districts: Makoni and Shamva (CIMMYT, 2012). Although evidence on the effectiveness of hermetic storage technologies exists (Bravo, 2009; CIMMYT, 2011; Tefera et al., 2011; CIMMYT, 2012; Bern et al., 2013), there has not been enough empirical evidence of economic and financial viability to back this in the smallholder farming systems of developing countries in southern Africa. Furthermore, highly effective technology for protection is often expensive and its adoption will be limited unless it is profitable (Jones et al., 2014). Besides, economic analysis of storage technologies particularly, for maize, are also not well documented (Kimenju and de Groote, 2010) and in some instances, these have been promoted without being subjected to economic analysis; forcing farmers to adopt technologies available to them without full information on their performance.

More so, aspects of affordability and farmers' willingness to pay (WTP) for hermetic technologies have not been researched in Zimbabwe and the region at large. Thus, understanding the factors that influence farmers' WTP for a new storage technology is critical to design appropriate storage technology dissemination programmes and to inform policy. Since these hermetic technologies are new to smallholder farmers, it is critical to understand factors that influence their choice of storage technology and thereby inform further dissemination of hermetic technologies. More so, results from this study will provide a basis for evaluating the adoption of the hermetic technologies in Zimbabwe. On the other hand, while a number of studies focused on grain protection methods (Mvumi and Stathers, 2003; Gadzirayi et al., 2006; Parwada et al., 2012; Muzemu et al., 2013; Chigoverah et al., 2014; Makaza and Mabhegedhe, 2016) in post-harvest management of maize grain, little attention has been given to factors that influence smallholder farmers' choice of storage practices in Zimbabwe. It is against such a background that storage technology remains critical among smallholder farmers to improve household incomes, food security and livelihoods.

1.2 Research problem

Little attention has been paid to the economics of post-harvest losses (PHL) and storage technology in studies on household grain management; and governments have not adequately addressed the issue of reducing PHL (EGSP, 2012). This is despite the potential impact of PHL on household food security, incomes, and livelihoods. Significant quantities of food are lost in storage at farm level due to spoilage and insect infestation. In Africa alone, PHL of about 20-30% valued at US$4 billion dollars is recorded annually (CIMMYT, 2011) in a continent where almost 30% of the people (200million) are malnourished (Nukeine, 2010). This PHL is equivalent to the food aid Africa received in the last decade or is equivalent to annual caloric requirements of 48 million people (World Bank, 2011; CIMMYT, 2012). The significance of effective storage technologies is therefore not overstated as poor post-harvest management of cereals has been cited as one of the major challenges to food security in sub-Saharan Africa (Tefera, 2012). Poor post-harvest management of cereals accounts for 15-30% of annual grain losses (World Bank, 2011) thereby aggravating hunger (Tefera, 2012).

Besides the fact that improved storage technologies exist in the market, their uptake is still very low yet there is potential for great gains in food security (Ndiritu, 2013; Chigoverah et al., 2014). In Zimbabwe, smallholder farmers still rely on traditional storage practices which cannot guarantee the protection of staple food crops like maize against major storage pests. Considering the low agricultural productivity recorded among many poor smallholder farmers in Zimbabwe (FEWSNET, 2016), PHL can have adverse effects on the food security of both the farmers and of the country at large. Thus PHL is increasingly being recognized as part of a vital approach to realizing agriculture's full potential to meet the world's increasing food and energy needs (World Bank, 2011). Therefore, interventions in PHL reduction are seen as an important strategy to reduce food insecurity in sub-Saharan Africa (SSA) and to reduce poverty.

It is thus imperative to determine the factors that influence storage practices of smallholder farmers in Zimbabwe, in the face of continued PHL in storage. Moreover, the adoption of new improved technology has always been problematic among farmers in developing countries like Zimbabwe (Ndiritu, 2013). Besides, very few countries, from which a country like Zimbabwe can learn from, assess the adoption of agricultural storage technologies thus there is a gap of knowledge in this regard. Tefera et al. (2011) also pointed out that there is scarcity of evidence on the determinants of adoption of improved post-harvest technologies as farmers in sub-Saharan Africa continue to practice their traditional storage methods. As a result, huge PHL are incurred along the value chain at the farm level. These storage losses may reduce the amount of grain available for consumption as well as for sale. This may also affect the maize marketing behaviour of smallholder farmers as farmers may be forced to sell their grain immediately after harvest when prices are low thus foregoing potential income gains later in the season when prices are high or marketable surplus is reduced due to the storage losses. This study sets out to analyse the influence of storage technology on this farmer maize marketing behaviour. The role of storage technology on farmers' grain selling and purchasing behaviour is still new in literature hence the study seeks to fill this gap.

The International Maize and Wheat Improvement Centre (CIMMYT), among other agencies and organizations behind PHL reduction, has embarked on the promotion of hermetic grain storage technologies among smallholder farmers in southern Africa, under a four-year project entitled ‘’Effective Grain Storage Project (EGSP) for Sustainable Livelihoods of African farmers", running from 2012 to 2016. The project is being implemented in three countries, including Zimbabwe. EGSP seeks to enhance household food security by reducing postharvest losses and increasing incomes of target farmers through the provision of improved post-harvest technologies. An economic viability of these new technologies has not yet been done hence this study seeks to fulfill this objective. Overall, this study supports CIMMYT's EGSP overall goal of enhancing household food security and incomes of smallholders.

1.3 Research objectives

The main objective of the study is to examine the determinants of grain storage practices, storage losses and their implications on farmer maize marketing behaviour and household food security. Specific objectives of the study are:

1) To quantify smallholder farmers' storage losses across storage practices.
2) To compare the economic viability of maize postharvest technologies.
3) To determine factors influencing the choice of grain storage practices.
4) To assess smallholder farmers' potential willingness to pay for improved grain postharvest technologies.
5) To determine the effects of grain storage practices on smallholder farmers' maize marketing behaviour.
6) To examine the effects of grain storage practices on smallholder farmers' hunger gap.

1.4 Organisation of the thesis

The thesis is organised into eight chapters. This includes the introductory and concluding chapters, a brief literature review chapter and five empirical chapters. The introductory chapter has provided the general study background, inspired the research problem and laid out the objectives of the study. The second chapter offers a brief overview of the literature on storage technology and storage losses among smallholder farmers in developing countries. The beginning of the chapter focuses on the importance of agriculture and maize in Zimbabwe. The chapter then discusses storage technologies, storage losses and storage technology adoption issues in developing countries. A brief discussion of the empirical literature that has investigated the various dimensions of storage technologies adoption and post-harvest losses impacts is presented in the same chapter. Although the study data was collected from the same study sites, Makoni and Shamva Districts, a separate description of data collection and sampling was given for each empirical chapter to show the differences in sample sizes and type of data collected from the farmers. Chapters 3 to 7 comprise the five empirical chapters of the thesis. The detailed descriptive summary of the households was given in each chapter. It must be noted, however, that, while efforts were made to minimise repetitions, the nature of the thesis presentation is such that repetition is inevitable. The five chapters of the thesis were derived from the same sample of farmers. Therefore, the inevitable repetitions in the descriptives of the sampled farmers in each chapter of the thesis.

Chapter 3 studied the factors that influence the choice of grain storage technologies among smallholder farmers. The focus was on the current storage practices that farmers use to store maize and how household socio-economic characteristics influence the choices made. Econometric techniques of discrete choice such as Multinomial logit were presented in this chapter. The chapter also presents results and discussions. Theory of random choice informs this analysis. Chapter 4 focuses on determining smallholder farmers' WTP for a metal silo and like Chapter 3, this is grounded in the random utility framework. The chapter analyses data using logit model and presents the results and discussion. The focus of Chapter 5 and Chapter 6 is on examining the effects of grain storage technologies on smallholder farmers' maize marketing behaviour and household hunger gap and its intensity, respectively. The chapters analyse data using ordered probit and double-hurdle models. Chapter 7 quantifies storage losses across storage practices and compares the financial profitability of hemetic technologies versus farmers' traditional storage technologies. The framework of the cost benefit analysis is used for data analysis.

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CHAPTER 2 AN OVERVIEW OF GRAIN STORAGE, STORAGE LOSSES AND STORAGE PRACTICES AMONG SMALLHOLDER FARMERS

2.1 Introduction

Agriculture still plays an important role in the economies of developing countries in Southern Africa. In Zimbabwe, the contribution of agriculture towards Gross Domestic Product (GDP) is between 15% and 20% depending on the rainfall patterns and other macroeconomic factors (Government of Zimbabwe, 2012; Zimbabwe Economic Policy Analysis and Research Unit, 2014). The agricultural sector also provides 40% of export earnings while it supplies 63% of agro-industrial raw materials and provides more than half of the country's caloric intake (Kapuya et al., 2010). Grain crops account for at least 50% of Zimbabwe's cultivated land area and overall agricultural output, with maize being the most produced grain cereal crop in the country.

Maize is a staple food crop for the majority of the population in Africa, accounting for 40-50% of the calorie consumed by the poor in Southern Africa, including Zimbabwe (Smale et al, 2011). Over 90% of the population in the Southern African region use maize as their staple diet (Wambugu et al., 2009; Zinyengere et al., 2011) among other uses such as animal feeding (Kapuya et al., 2010). This places maize crop at the center of Zimbabwe's agricultural sector making the sector strategic and very important in designing strategies and policies to reduce poverty, attain domestic food security and boost smallholder farmers' incomes.

According to Mhiko et al. (2014), about 70% of the maize produced in Zimbabwe is stored on the farm for household consumption and farm level enterprises. Safety of this stored maize is thus crucial in order to reduce storage losses; hence storage technology is important to achieving household food security. Overall, storage issues, therefore, occupy a vital role in the livelihoods, food security and incomes of smallholder farmers in the country. Very few studies, however, looked at storage technologies and losses in the country and it is the thrust of this study to contribute to this body of knowledge. The following sections discuss the role of storage at the farm level, storage losses, storage practices, and technology among smallholder farmers in developing countries.

2.2 Significance of grain storage

The significance of storage is becoming increasingly relevant to smallholder farmers globally. Storage of critical crops such as maize plays an important role in achieving food security in developing countries (Kimenju and de Groote, 2010) since agricultural production, particularly that of most cereals is done on a seasonal basis. Smallholder farmers usually have one harvest per year which in itself may be subject to failure due to the vagaries of nature (Chikobvu et al., 2010; Stathers et al., 2008).

As in most southern African countries, maize production in Zimbabwe is mainly rain fed and smallholder farmers rely on a single harvest per year. This places the lives of thousands of rural farmers at risk of food insecurity and poverty as the country is often exposed to frequent dry spells and floods. Given this background, storage is thus considered crucial in the agricultural sector of the country in order to even out supply fluctuations from one season to the other and throughout the year. In other words, storage helps remove produce off the market during surplus seasons only to release it back in lean seasons (Gitonga et al., 2013). Smallholder farmers, therefore, benefit from storage when they avoid immediate sales after harvest when the market prices are low and participate in the market when prices become favourable. This behaviour is sustained when storage technology is effective against storage pests and infestations.

On the other hand demand for staple crops is constant throughout the year, thus making storage very important to meet daily and future consumption needs of smallholder farmers. Grains such as maize are among the most important staple foods with social, economic and cultural values in developing countries. Therefore the importance of grain storage as part of the marketing, distribution, and food security system, particularly maize, a staple crop in Zimbabwe, is well recognized. Safe storage of grain for longer periods varying from one month up to more than a year is thus required in a country where production is seasonal and is often exposed to unpredictable and varying weather conditions. Evidence from literature points out that about 70% of the maize produced in developing countries is stored on the farm for household consumption and farm level enterprises (Chakraverty, 2004; Nyambo, 2008).

Whilst storage plays a vital role in the post-harvest chain, significant grain losses are however incurred while in storage. Stored grain is actually at risk of storage pest infestation and attacks, rodents, birds and even human theft. This calls for effective grain storage practices that keep the grain safe in order to reap optimum benefits of storage at the farm level.

2.3 An overview of storage losses in SSA

Given the role of storage in achieving food security, poverty alleviation and improving household incomes, it is imperative to look at the safe storage of grain and understand the losses that are incurred particularly in the maize stores of smallholder farmers in Zimbabwe; otherwise, the gains from storage may be eradicated. According to Sekumade and Oluwatago (2009), huge losses of grain are being recorded in storage weakening the food self-sufficiency status of households and putting their livelihoods at risk. The value of PHL for cereals alone in Africa is estimated at more than US$4 billion annually and this worsens the food security situation of a continent where cereals constitute about 55% of the food basket; with maize being the preferred staple for about 900 million poor consumers and about one-third of all malnourished children (FARA, 2009; FAO, 2010; WB, 2011).

In southern Africa, storage losses of grain vary from 20-30% and storage losses are recognized as critical constraints upon food security among resource-poor farmers across Africa (Owusu, 2001; Owusu et al., 2007). Smallholder farmers throughout sub-Saharan Africa, incur grain losses of their stored produce due to insect damage (Stathers et al., 2008). As reported in Kamanula et al. (2010), insect pests are actually responsible for about 30% of PHL in grains in SSA. Increasing outbreaks of devastating storage pests in Africa at large is also worsening the PHL problem in the grain sector of developing countries. The maize weevil and the larger grain borer (LGB) are considered to be the major pests causing havoc in maize stores in Africa (Kimenju and de Groote, 2010; Kamanula et al., 2010). These granivorous insects pose a risk to household food security as they feed on stored grain causing quantitative, qualitative and economic losses (Chigoverah et al., 2014). These losses contribute to high food prices by removing part of the food supply from the market (Tefera, 2012).

In the east and southern Africa, post-harvest losses of grains such as wheat, sorghum, and maize may reach 10-20% (WB, 2011) as insect pest infestations continue to dominate as major causes of the PHL in grains (Rugumamu, 2009). The LGB is however considered to be the most notorious storage pest of maize causing more than twice the weight loss in maize than infestations of indigenous pests such as maize weevil (Stathers et al., 2008). This pest causes losses of maize that can be as high as 30-40% over a period of 6 months of storage (Mukanga et al., 2010) and in extreme cases can lead to complete destruction of stored grain if left untreated (Tefera, 2012; Singano and Nkhata, 2004). PHL of up to 80% was reported on shelled maize after six months of storage in Malawi (Singano et al. (2007) in Kasambala and Chinwada (2011)), while in Zimbabwe, a FAO survey reported 92% of PHL (www.fao.org/3/a-av013e.pdf). Such high PHL can actually lead to famine country-wide.

As already highlighted above, insect pests cause storage losses that can be both qualitative and quantitative in nature. Qualitative loss refers to the damage or contamination of grain leading to nutritional loss whereas quantitative loss is a reduction in weight of grain that can be quantified and valued (Tefera, 2012). The quantitative loss is easier to measure as compared to the qualitative loss which is subject to individual judgment.

Therefore this study compares the quantitative loss of grain in both the traditional and improved storage practices using the on-station trials data. The results of the analysis help to determine where huge storage losses occur in smallholder farmers' storage technologies and thus inform recommendations of better storage technologies for improved food security and incomes. Without proper management, PHL can hamper the achievement of the Sustainable Development Goals of eradicating poverty and zero hunger by 2030.

Loss estimates, in general, are not reported by storage structure but rather for the storage period in a particular location. Eliciting loss levels by storage practice/structure helps to inform any decisions meant at improving storage technologies. Very few studies have looked at determining the level of storage losses in traditional and improved storage technologies in Zimbabwe. One notable study is by Mhiko et al. (2014) that was carried out in Makonde District in Mashonaland West province. The study assessed the efficiency of improved and traditional granaries in protecting traditional and hybrid maize from Prostephanus truncatus (LGB) and concluded that traditional granaries are more prone to Prostephanus truncatus infestation than the improved granaries.

This study, however, uses on-station trials loss data to compare storage losses in four storage technologies, namely, hermetic metal silo, super grain bag, insecticide-treated polypropylene bag and untreated polypropylene bag. It is also crucial to understand where huge storage losses occur in these storage practices so as to inform farmers of the benefits of adopting improved storage technologies. Such studies have not yet been done in Zimbabwe and this paper seeks to gather evidence of these storage losses to enhance the adoption process of new storage technologies among smallholder farmers in Zimbabwe.

2.4 Traditional grain storage practices

Smallholder farmers in southern Africa rely on traditional storage practices to store maize grain (Tefera, 2012). Traditional storage structures are made from locally available materials such as plant materials and soil. Farmers construct these structures themselves (Tefera, 2012). However, the materials used to construct the storage structures are not effective enough to offer safe storage to grain and thus predispose grains to serious attacks from biotic constraints such as insects, rodents, and birds (Nukeine, 2010). With the outbreak of devastating storage pests such as the LGB, which is capable of damaging a variety of food commodities including wooden objects, drying timber and leather (Rwegarasiya et al., 2003), the safe storage of grain in these storage structures is at a risk. Generally, smallholder farmers use traditional storage structures because they are relatively inexpensive to construct since locally available materials are used to construct them (Adejumo and Raji, 2007; Mhiko et al., 2014).

Examples of traditional storage practices that smallholder farmers in Africa use include woven baskets, open platforms, gourds, cribs, thatched rhombus, mud and pole/brick granaries, jute bags, metallic drums, bins, calabashes, earthenware pots and plastic bags (Nukeine, 2010; Nyagwaya et al, 2010; Tefera, 2012; Mvumi et al., 2013).

These practices also vary from country to country. Storage practices that smallholder farmers in Zimbabwe use vary from traditional granaries (pole and mud; brick and mud) under thatch roof to improved traditional granaries (brick and cement, with concrete floors). Most of these structures are not moisture proof, rodent proof and also not air-tight. Specifically, the majority of smallholder farmers in Zimbabwe store their grain in a shelled form packaged in polypropylene bags, jute bags, cotton wool bags in pole and dagga or mud granaries or rooms in houses (Mhiko et al., 2014).

The outbreak of the LGB in the country exposes smallholder farmers' grain stores to serious potential pests' hazards. In Zimbabwe, LGB was discovered during the 2006/2007 agricultural season (Mhiko et al., 2014), though it was officially declared in the country in 2010 (Nyagwaya et al., 2010). This study, therefore, sets to determine the factors that influence the choice of grain storage practices among smallholder farmers in Zimbabwe in order to inform decisions on promotion of improved storage technologies and explain why farmers continue to use traditional storage technologies that do not offer effective protection to the stored maize grain leading to potential huge PHL.

2.5 Stored-products protection methods

Smallholder farmers, on the other hand, have adopted several preservation methods to protect their stored grain from pest and rodents' attacks. These include the use of insecticides such as ACTELLIC dust, plant and other botanical products including ash, and gum tree leaves. In Zimbabwe, according to Mvumi and Stathers (2003), control of insect pests in stored maize grain has been based on curative chemical methods and several studies in Zimbabwe have looked at the effectiveness of these methods in protecting grain against major storage pests such as maize weevil and LGB (Mvumi and Stathers, 2003; Gadzirayi et al., 2006; Parwada et al., 2012; Muzemu et al., 2013) and not on factors that influence grain storage practices, adoption of improved storage technology, the economic viability of improved storage technology and impact of storage technology on smallholder farmers' maize marketing and household hunger gap. These are new areas of study in the literature of storage technology in Zimbabwe and hence the need for this study to seek answers and contribute to the body of knowledge in that regard.

2.6 Improved grain storage technologies

More so, increasing PHL in grain storage among smallholder farmers who are apparently relying on traditional storage practices, against an environment exposed to high risk of pest infestations such as LGB is justification enough to stimulate development and promotion of improved storage technologies that are effective against insect damage among other storage risks. Investment in improved grain storage technologies has the potential to reduce postharvest losses and enhance food security and increase incomes of smallholder farmers in Africa.

Recently, hermetic storage technologies have been developed in the storage sector to meet household storage needs at the farm level. These are metal silos and super grain bags (Kimenju and de Groote, 2010; Tefera et al., 2011; Maonga et al., 2013). This development is considered noble yet success stories in promoting improved on-farm storage technologies have indeed been rare in SSA (WB, 2011) and thus there is a gap in understanding factors that influence adoption of improved storage technologies and it is one of the objectives of this study. Besides understanding the adoption factors of these new improved storage technologies, it is also necessary to carry out an economic viability study in order to inform decision-makers on the costs and benefits of the technologies. The technologies are new to Zimbabwe, making the economic viability study one of the first in the country and very relevant to policymakers working at promoting the technologies among smallholder farmers in the country.

Whilst evidence suggests that many traditional storage facilities do a reasonable job of preventing post-harvest losses, the introduction of hybrid varieties and new pests such as LGB, has rendered some of these technologies less appropriate (Hodges, 2007). There is, therefore, need to develop effective storage systems that protect stored grain from pests attacks.

Reducing storage losses is significant since maize is the primary staple food crop in Zimbabwe and a source of livelihoods to a majority of smallholder farmers who contribute about 70% of the total output. CIMMYT in partnership with the Ministry of Agriculture, Mechanization, and Irrigation Development initiated the Effective Grain Storage Project (EGSP) for Sustainable Livelihoods in 2012, in Zimbabwe, under a four year pilot phase (EGSP, 2012). Improved storage technologies in the form of hermetic metal silos and super grain bags were demonstrated among smallholder farmers in Shamva and Makoni districts. The on-station and on-farm trials tested the effectiveness of the technologies in reducing PHL but apparently no economic analysis was done to determine smallholder farmers’ profitability of adopting the technologies. This study thus seeks to fill this gap using a Cost-Benefit Analysis (CBA) approach.

2.7 Factors influencing household storage practices among smallholder farmers

Most of the research in the late 1960s was focused on assessment of the prototypes of storage structures that farmers used (Gilman and Boxall, 1974). However, later research to date has focused on improving traditional granaries for better durability, air tightness among other attributes (Adetunji, 2007). Research has been focused on production side of the equation, on how to increase crop productivity, factors influencing adoption of various hybrid crop varieties, conservation techniques (Arellanes and Lee, 2003; Herath and Takeya, 2003; Lee, 2005; Pender and Gebermedhin, 2007; Kassie et al., 2009; Wollni et al., 2010; Kassie et al., 2012) at the expense of understanding storage decisions. It is imperative to understand the various factors underlying farmer's choice of current traditional practices in order to inform adoption decisions of better and improved storage technologies. Assessing factors influencing storage practices of smallholder farmers will provide the basis for coming up with informed policies to enhance adoption decisions of improved storage technologies. This study seeks to determine factors that influence smallholder farmers' storage practices in Zimbabwe.

2.8 Food security and storage among smallholder farmers

In Zimbabwe, maize grain storage is critical to the achievement of household food security as at least 70% of the population directly depends on agriculture for their livelihood (Ministry of Agriculture, 2012). It is widely grown by smallholder farmers who contribute about 50% to the national production (Rukuni et al., 2006; Kapuya et al., 2010). Maize production is seasonal as it mainly relies on rain-fed agriculture. Approximately 16% of rural households and almost 1.5million people are food insecure during the peak hunger season between January and March (UNICEF, 2016). According to ZimVac (2016), 42% of the rural population is food insecure during the hunger season. Food insecurity is persistent in Zimbabwe with at least 12% of the rural population experiencing it over the last five years (WFP, 2014). Maize is stored between August and March and households incur losses during this period (WFP, 2014). Households may go for some months with no maize in stock, due to storage losses. Costa (2014) estimated losses to be as high as 60% in maize grains after storing them for 90 days in the traditional storage structures (Granary/Polypropylene bags) in Uganda. The outbreak of storage pests such as the larger grain borer threatens the household food security in Zimbabwe.

Several studies have looked at the determinants of food security in varying contexts (urban/rural), and levels (regional, national, local) using different variables and methodologies (Muhoyi et al., 2014). Some studies focused on household socioeconomic characteristics such as the age of household head, household size, education years, the gender of household head, and marital status as the main drivers of food insecurity (Sikwela, 2008; Gebre, 2012; Ngongi, 2013; Muhoyi et al., 2014). Other studies point out that access to extension services, land size, livestock, and off-farm income are key factors to achieving household food security (Amaza et al., 2009; Makombe et al., 2010; Matchaya and Chilonda, 2012). Sikwela (2008) singled out aggregate production, fertilizer, cattle ownership and access to irrigation as key factors in achieving household food security. Muhoyi et al. (2014) and Muzah (2015) looked at household food security in rural and peri-urban areas in Zimbabwe, respectively. Muhoyi et al. (2014), used the logit regression model to examine the determinants of household food security in Murehwa district where household size, farm size, land quality, climatic adaptation, livestock ownership were found to be significant. Ordered probit and Tobit regression models were used in Muzah (2015) to assess determinants of household food security.

2.9 Factors influencing household grain marketing behaviour among smallholder farmers

On the other hand, the theory of seasonal price fluctuations has failed to totally explain the behaviour of smallholder farmers, where they are found to dispose of their grain immediately after harvest when prices are low and only to buy it back in the lean season when prices are high (Proctor, 1994). This behaviour undermines household food security and reduces farmers' incomes. Although storage losses continue to plague stored maize grain, storage technologies are overlooked in household grain management studies, and in explaining farmer storage behaviour. In fact, in most studies, storage technologies are included in the overall storage cost (Fulgie, 1995 in Didier et al., 2013) to the extent that there is no measure of the isolated effect of storage technologies on farmer grain marketing behaviour. Despite notable evidence that a larger part of stored losses among smallholder farmers of developing countries is due to lack of access to effective modern storage technology, less effort has been directed at understanding the impact of storage technology on household grain marketing behaviour in southern Africa. This study seeks to fill this gap in the literature and thus hypothesizes that storage technologies have a significant effect on grain marketing behaviour or patterns of smallholder farmers in Zimbabwe.

2.10 Factors influencing household technology adoption among smallholder farmers

Moreover, adoption of agricultural technologies in developing countries is still problematic. Farmers consider a multiplicity of issues when deciding to adopt a new technology. Both farm and farmer characteristics have been found to influence adoption decision. Empirical evidence also suggests that characteristics or attributes of the technology play a significant role in the adoption process. Kamla-Raj (2009) found that age, farm size, farming experience and contact with extension agents significantly influence farmer's adoption of improved Yam storage technology. Farmer's socio-economic characteristics play a significant role in influencing technology adoption decision, for example, farmer education was found to positively influence adoption of technology (Onemolease, 2005) while farm size, age, education and access to agricultural extension were found to positively influence adoption of small metallic grain silos in Malawi (Maonga et al., 2013). Ignorance of technology existence, non-availability and the high cost of technology are mentioned in literature as factors that may constrain the decision to adopt by farmers.

On the other hand, farmers constantly face decisions about whether to invest in a new storage or post-harvest loss reduction method with increasing risk and uncertainties or to maintain the current practice without new risks and uncertainties. Faced with increasing levels of PHL smallholder farmers are almost always forced to adopt any improved storage technologies available even without understanding the full costs and benefits of doing so (Kimenju and de Groote, 2010). Economic analysis of storage technologies, particularly maize is not well documented. Moreover, investments in improving technologies for maize storage have been on the lower side compared to investments in improving crop productivity. Upcoming technologies for maize storage have sometimes been promoted without being subjected to trials and economic analysis (Kimenju and de Groote, 2010). Hermetic storage technologies in Africa are very recent, having been introduced first in Kenya in 2008 through SDC/CIMMYT project initiatives. In Zimbabwe, the improved storage technologies (metal silos and super grain bags) reached the smallholder farmers in 2013 and thus literature on economic analysis is not yet available. This study is the first in the country and second in Africa, following Kimenju and de Groote (2010)'s study in Kenya, to determine the profitability of metal silos and super grain bags versus current farmer practice of storing shelled maize grain in polypropylene bags and treating with actellic super dust. The farmers' location-specific conditions of Kenya and Zimbabwe are different therefore the performance of the technologies is likely to be different. The purpose of the economic analysis is to aid farmers' and policymakers' decisions to adopt and scale-up the technologies, respectively.

On the other hand, evidence of Willingness to Pay (WTP) for agricultural storage technologies is scant. In general, following Aryal et al. (2009), farmers' WTP is a function of knowledge, attitude, and intention. Available information influences both knowledge and attitude toward the proposed technology. Socioeconomic characteristics such as gender, income, and age also shape farmers' WTP. Application of WTP in agriculture is, however, varied; Holloway and Ehui (2001), for example, looked at the impacts of extension on the participation of dairy producers in Ethiopia's milk market and the WTP for the extension service. Asrat, Bellay, and Hamito (2004) examined the determinants of farmers' WTP for soil conservation practices in Ethiopia's south-eastern highlands. For both studies, farmer education was found to influence WTP for the agriculture technologies. A higher level of education is expected to increase farmers' ability to get and process and use information. On the other hand, both farm and non-farm incomes are also expected to increase farmers' decision to invest in agricultural technologies. Other studies have reported a positive relationship between income and adoption of agricultural technologies (Holden and Shiferaw, 2002; Faye and Deininger, 2005).

Farmers' decision processes for adoption of agricultural technology are discrete in nature thus qualitative models are often most appropriate for analytical purposes of WTP and choice of storage technology. Such models include the linear probability model, the probit model (Hausman and Wise, 1978; Mcfadden, 1981) and the logit model (Press and Wilson, 1978; Jones and Landwehr, 1988).The error term for the Probability Model has elements of non-normality and the predicted value of the dependent variable may not fall within the unit interval, making the model less appropriate for analysis of discrete nature (McFadden, 1981). However, among the discrete choice models, the Multinomial Logit (MNL) and the Multinomial Probit (MNP) models are the most commonly used models. Technically, the models are similar except for the nature of the distribution of the error terms. Categorical dependent variables are nonlinear and thus the Ordinary Least Squares method can no longer produce the best linear unbiased estimator (BLUE) (Park, 2006). In categorical dependent variable models, the dependent variable is binary, ordinal or nominal. Binary responses (0 or 1) are modelled with binary logit and probit regressions. Ordinal responses (1^{st}, 2^{nd}, 3^{rd} ...) are formulated into generalized ordered logit or probit regressions whilst nominal responses (unordered) are analysed using Multinomial Logit (MNL), Multivariate Probit (MVP), Conditional Logit, or nested Logit models. Categorical Dependent Variable Models adopt the maximum likelihood (ML) estimation method and the choice between the logit and probit models are more closely related to estimation and familiarity rather than theoretical and interpretive aspects (Gujarati, 2004; Green, 2008). Different forms of regression models, namely Logit, Probit, Multinomial Logit and Multivariate Probit models have been used to analyse farmers' choice of agricultural practices. Maonga et al. (2013) used the probit model to analyse the adoption of small metallic silos in Malawi. Logistic regression models were used in Atibioke et al. (2012), for assessing effects of demographic factors on the adoption of grain storage technologies in Nigeria.

The multinomial Logit model was used in this study to analyse factors influencing smallholder farmers' choice of storage practices in Zimbabwe while binary logistic regression model was used to determine smallholder farmers' willingness to pay for metal silo storage technology and to analyse the effects of storage practices on household hunger gap. Ordered probit was used to determine the effects of grain storage technologies on smallholder maize marketing behaviour.

2.11 Study area description

This study was undertaken in two smallholder farming areas of Makoni and Shamva districts in Zimbabwe. Based on the census results of 2012, Makoni district has a total population of 272 340 while Shamva district has a total population of 123 650 (ZIMSTAT, 2014). Both districts lie in Natural Region II, which has a mean annual rainfall of 800-1000mm suitable for intensive crop and pasture production (WFP, 2014). Maize is a major and widely grown staple cereal crop in the areas and it relies on rain-fed agriculture. Both areas often experience bumper harvests thus demanding storage technologies. Agriculture is the main occupation of the people in these areas. The International Maize and Wheat Improvement Centre (CIMMYT) disseminated new storage technologies of metal silos and super bags in the districts in 2013 on a pilot basis through the Ministry of Agriculture, Mechanization, and Agriculture Development. This, coupled with the fact that maize is the dominant staple crop grown in the areas make both districts suitable study areas for this study. Different sample sizes for the district was however as a result of missing data in some key variables for the study such as production of maize and hence some households were dropped from the analysis leading to the different sample sizes.

2.12 Sampling and data collection tools

Primary data for the study was collected between June and November 2015 using a pre-tested structured questionnaire. Trained and experienced enumerators administered the questionnaires in face-to-face interviews. These enumerators had good knowledge of the rural farming systems and could speak the local Shona language. Questionnaire pre-testing using 20 households was done before the main survey. The survey was conducted using the multistage sampling technique. This was done in consultation with the district agricultural extension officers of the Department of Agriculture, Extension and Technical Services (AGRITEX).

Firstly, two districts, namely Shamva and Makoni, were purposively selected in Mashonaland Central and Manicaland Provinces. Both districts were targeted for the CIMMYT hermetic metal silos and super grain bags pilot project and represented major maize production areas in the country. Secondly, six wards, from each district, were purposively selected using the same criteria above. Thirdly, 12 enumeration areas (EAs) were randomly selected from each ward, thus a total of 24 EAs were selected for the study. The Zimbabwe National Statistics Agency (ZIMSTAT) provided the list of EAs. Finally, a total of 417 households were randomly selected from the EAs using the proportionate sampling method without replacement. Out of the total sample, 229 households were from Makoni District while 188 households were from Shamva district. Extension workers assisted the enumerators to locate the villages and the respective village heads, who then helped to direct the enumerators to the selected households.

The questionnaire, attached as appendix A, included several modules, which include information on basic household characteristics such as sex, age, marital status and education level; livestock assets; animal products; equipment, implements and gadgets; land ownership, access and use; cropping and harvest; crop sales; maize plot management; vegetable production; investments and ownership of grain handling structures; maize storage patterns and loss assessment; sufficiency of own maize harvest for household consumption; household maize selling behaviour; household maize purchasing behaviour; insecticide use (awareness, informants and precautionary behaviour), non-metal silo users, off-farm income and remittances and formal or informal business activities. The questionnaire also captured the views of households on the viability of commercial maize production under the current marketing conditions. While the household characteristics module is relevant to all chapters of the study, some modules are relevant to specific chapters and hence are presented accordingly.

2.13 Summary

The empirical literature has shown that storage and storage technology are critical components of the post-harvest value chain with multifaceted repercussions on household incomes, food security and livelihoods. However, there is scanty evidence on storage losses by storage practice in the country. Determining the severity of the problem will thus justify the promotion of improved storage technologies among smallholder farmers. The review has shown that very little research has been done on the economics of grain storage in developing countries and in particular, economic analysis of improved storage technologies. More so, no study has been done in the country to determine smallholder farmers' WTP for a metal silo storage technology. Little attention has been paid to understand how storage technology affects household maize marketing behaviour and household hunger gap. Choices of storage practices play a vital role in contributing to food security and livelihoods of smallholder farmers in Zimbabwe. Smallholder farmers still rely on traditional storage technologies which do not guarantee adequate and safe storage of grain against recent outbreaks of notorious maize storage pests such as the LGB. The next five empirical chapters seek to fill this gap by examining the determinants of grain storage practices, storage losses and their implications on farmer maize marketing behaviour and household food security.

To achieve the study objectives, a total of 417 households were randomly selected in two farming districts of Zimbabwe. Makoni and Shamva districts in Manicaland and Mashonaland Provinces, respectively, were purposively selected for the study. These districts represent the major maize growing areas in the country, which often experience bumper harvests thus demanding storage technologies. Maize is a major and widely grown staple cereal crop in the areas and produced under rain-fed conditions. CIMMYT, in 2013, promoted a new storage technology, hermetic metal silos. It was thus imperative to target these study areas in analysing the determinants of grain storage practices, storage losses and their implications on farmer maize marketing behaviour and household food security in Zimbabwe.

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CHAPTER 3 FACTORS INFLUENCING SMALLHOLDER FARMERS' CHOICE OF STORAGE TECHNOLOGIES IN ZIMBABWE

3.0 Abstract

This chapter was directed at finding out the factors that influence smallholder farmers' choice of grain storage technologies in Zimbabwe. A total of 417 rural households, randomly selected from Zimbabwe's two districts of Makoni and Shamva, were analysed using the Multinomial logit model. The empirical results showed that income from business and wages had a negative and significant influence on farmers' choice of insecticide storage. This could mean that farmers participating in business and wage-earning activities are less likely to store maize grain. Although the empirical results indicated that access to extension had a negative influence on farmers' choice of storage technology, provision of extension services that are tailor-made to improve farmers' knowledge on post-harvest technologies could positively influence their choice of storage technologies. Conversely, the total quantity of maize grain farmers stored showed a positive and significant influence on their choice of storage technology. Farmers with higher quantities of stored grain were more likely to choose insecticide storage technologies than their counterparts. This means that farmers are rational and as such will choose to invest in storage when they expect to reap optimum benefits. Older household heads had higher chances of using the insecticide storage technology indicating that farming experience influences the choice of grain storage technologies. Marital status, likewise, increased the chance of using the insecticide storage technology suggesting that married household heads are less risk-averse. Households with a higher value of non-food crops had higher chances of using insecticide technology compared to their counterparts. Education years positively influenced the choice of storage technologies. Therefore, the study recommends that government should target older household heads, married household heads for promotion and dissemination of storage technologies. The government should develop programs that support the production of non-food crops in smallholder areas without sidelining maize production. In addition, the government should increase access of farmers to education by developing adult learning programs in the areas.

Keywords: Storage, Choice, Maize, Multinomial Logit, marginal effects, Zimbabwe

3.1 Introduction

Farmers in southern Africa face many constraints when producing staple food crops and have various challenges in post-harvest grain management (Didier et al., 2013). Access to storage technologies remains problematic throughout the post-harvest chain and has multi-faceted impacts on household food security, incomes and general livelihoods of smallholder farmers.

Generally, smallholder farmers in southern Africa, Zimbabwe included, rely on traditional storage practices to store maize grain (Tefera, 2012). These traditional storage practices made from locally available and often cheap materials are prone to pest and rodent attacks (Tefera, 2012).The materials used for constructing the storage structures are not effective in creating safe storage for grain and thus predispose the grains to serious attacks (Nukeine, 2010). Examples of traditional storage practices that smallholder farmers in Africa use include woven baskets, open platforms, gourds, cribs, thatched rhombus, mud and pole/brick granaries, jute bags, metallic drums, bins, calabashes, earthenware pots and plastic bags (Nukeine, 2010; Nyagwaya et al., 2010; Tefera, 2012; Mvumi et al., 2013).

In general, smallholder farmers use traditional storage structures because they are relatively inexpensive to construct since locally available materials are used to construct them (Mhiko et al., 2014; Adejumo and Raji, 2007). These practices also vary from country-to-country. With the outbreak of a devastating storage pest such as the larger grain borer (LGB), which is capable of damaging a variety of food commodities including wooden objects, drying timber and leather (Rwegasiya et al., 2003), the safe storage of grain in these storage structures is at a risk. Smallholder farmers in Zimbabwe store their grain in shelled form, packaged in polypropylene bags, jute bags, cotton wool bags in pole and dagga or mud granaries or rooms in houses (FAO, 2010; Mhiko et al., 2014).

In order to preserve their maize grain in storage, the farmers use a wide range of stored-product protection methods; which include actellic dust, plant and other botanical products such as ash, and gum tree leaves (Mvumi and Stathers, 2003). The efficacy of these protection methods is dwindling as pests such as the LGB and maize weevils develop resistance to them. Besides this, the use of insecticides is receiving much focus of late due to the rising environmental and farmer health concerns. According to Adejumo et al. (2014) and Hossard et al. (2014), the residual products of insecticides are toxic and their continuous use can lead to environmental pollution and health hazards. Misuse of the insecticides has also resulted in the loss of grain in storage.

Nevertheless, advancements in grain storage technologies have resulted in the introduction of more effective hermetic grain storage technologies (de Groote et al., 2013). Namely, these are the metal silo and super grain bags. According to Joseph et al. (2012), use of hermetic technologies can lead to better quality grains, less usage of pesticides and hence directly contribute to rural development and poverty reduction. Hermetic technologies are new in Zimbabwe, and the International Maize and Wheat Improvement Centre (CIMMYT), with support from the Swedish Development Cooperation (SDC), introduced the technology on a pilot basis in 2012, targeting two farming districts: Makoni and Shamva (CIMMYT, 2012).

Since these hermetic technologies are new to smallholder farmers it is critical to understanding factors that influence their choice of storage technology and thereby inform further dissemination of hermetic technologies. More so, results from this chapter will provide a basis for evaluating the adoption of the hermetic technologies in Zimbabwe. While a number of studies focused on grain protection methods (Mvumi and Stathers, 2003; Gadzirayi et al., 2006; Parwada et al., 2012; Muzemu et al., 2013; Chigoverah et al., 2014; Makaza and Mabhegedhe, 2016) in post-harvest management of maize grain, little attention has been given to factors that influence smallholder farmers' choice of storage practices in Zimbabwe.

This chapter intends to fill this gap in the literature, as a choice to storage technology has a potential impact on household food security and incomes. The subsequent sections of the chapter look at research methodology, theoretical framework, and then present the results and discussion, conclusion and recommendations last.

3.2 Research methodology

3.2.1 Data

This chapter uses primary data collected from 417 households in two farming districts as outlined in the previous chapter. A pretested structured questionnaire administered at the household level contained a number of modules, some of which have been briefly discussed in the previous chapter. The modules presented in chapter 2 that are relevant to this chapter include basic household demographic and socioeconomic characteristics; land ownership, access and use; livestock assets; equipment, implements and gadgets; salaried/business income activities; vegetable production; crop sales and insecticide use (awareness, informants and precautionary behavior). The module specific to this chapter was that capturing maize storage patterns and loss assessment.

3.2.2 Conceptual framework and selection of variables

The theory of rational choice, also known as a choice theory or rational action theory, guides the microeconomic behaviour of smallholder farmers. According to Lawrence and Easley (2008), the rational choice theory provides the framework for understanding and modelling social and economic behaviour. The theory tries to explain what will happen when individuals are faced with a choice decision, for example, when smallholder farmers have to choose from several post-harvest storage technologies. The underlying assumption of the theory is that farmers are rational when choosing storage technologies. Rationality means that smallholder farmers consider the costs and benefits of post-harvest technologies and pick an alternative that is likely to give them the greatest satisfaction (Abudulai et al., 2014; Coleman, 1973).

Qualitative choice analysis methods are used to study this behaviour. The methods describe the discrete choices of smallholder farmers in choosing, in this case, a storage technology according to a number of explanatory variables. The choice models are developed from economic theories of random utility. Random utility theory assumes that a decision maker, such as a farmer, always chooses the alternative for which the value of utility is maximized.

In economics, utility refers to the real or fancied ability of a good or service to satisfy a human want (Okoruwa et al., 2009). Hence, using the concept of utility, the choice that a farmer will make or should make, among the available alternatives can be predicted or described. This is achieved by assigning a utility to each of the possible mutually exclusive alternatives. According to the principle of expected utility maximization, from Expected utility theory (EUT), a rational investor such as a smallholder farmer, when faced with a choice among a set of competing post-harvest storage technologies, acts to select that investment which maximizes expected utility. Expected utility theory assumes that preferences of smallholder farmers comply with the axioms of ordering, continuity, and independence (Starmer, 2000), and also that there is a utility function *U* that assigns a numerical value to each storage technology alternative (Hardaker et al., 1997). For example, if *Y* is a set of mutually exclusive choice objects (grain storage technologies) and a finite subset *D* of *Y* represents a decision problem (that is the farmer's behaviour is described by a random choice rule *p* which assigns to each decision problem a probability distribution over feasible choices), then the probability that the smallholder farmer chooses x ϵ *D* is denoted p *D*(x).

Table 3.1 outlines the dependent variable and exogenous factors hypothesized to influence the choice of storage technology among smallholder farmers in Zimbabwe. In general, the literature shows that farmers' age has a negative effect on technology adoption (Bocqueho et al., 2011). Older farmers are argued to be more reluctant to change hence the negative influence on technology adoption. However, other studies suggest that older farmers are more experienced and are not risk-averse hence are more likely to adopt new technologies than younger farmers (Atibioke et al., 2012). In this study, the influence of age on technology adoption is thus expected to positively influence the choice of grain storage technologies in this study. Age is measured in years.

Table 3.1**:** Exogenous variables used in the multinomial logit model

Dependent variable	**Definition**	**Measurement**	
Typestorage_tech	Type of storage technology used to store maize grain	1=Insecticide technology; 2=No insecticide technology; 3=Other technologies (storage that used smoking, biological treatment of grain using plant leaves, and ash)	
Exogenous variables	**Definition**	**Measurement**	**Apriori expectation**
Age	Age of household head	Years	+
Mar_status	Marital status	1=Married, 0=Otherwise	+
Sex	Sex of Household Head	1=Male, 0=Otherwise	+
Educyears	Education level of household head	Years	+
TTstored	Total quantity of grain stored	Kilogram	+
PCValuNONFOOD_Crop	Value of non-food crop income	USD	+
PCbusiwages_income	Business and wages income	USD	-
PCLivestock_value	Livestock value	USD	+
PCLandsize	Land size	Hectares	+
Extension_acc	Extension access	1=Yes, 0=Otherwise	+
PCEquip_value	Productive Equipment value	USD	+
PCVegetable_income	Vegetable sales income in a year	USD	+
Own_cell	Ownership of cellphone	1=Yes, 0=Otherwise	+

Although it is not known how marriage status influences the smallholder farmers' choice of grain storage technology (Maonga et al., 2013), marital status (M**ar_status**) of the household head is hypothesized to positively influence the choice of grain storage technologies among smallholder farmers in this study. **Mar_status** is a dummy variable that takes the value 1 if household head is married and 0 otherwise. This study argues that married household heads could easily make a unified decision with minimum risk aversion to choosing a grain storage technology that is deemed to improve household socioeconomic status.

The influence of gender on technology adoption has also been varied. Male-headed households are argued to be better positioned within society due to differential access to external inputs, information, and services (Lopes, 2010). Therefore, the sex of the household head (**Sex**) is postulated to positively influence the choice of grain storage technologies among smallholder farmers. The variable is a dummy taking on the values 1 if male-headed and 0 if female-headed.

The quantity of grain stored (**TTstored**) is an important factor that can influence the choice of storage technologies (Adetunji, 2007). It is measured in kilograms. The study expects total grain stored to positively influence the choice of grain storage technologies among smallholder farmers.

Education (**Educyears**) is expected to positively influence the choice of storage technology in this study. According to Adegbola and Gardebroek (2007), education improves farmers' ability to process information, allocate inputs more efficiently and also enables them to accurately assess the profitability of new technology compared to farmers with no education. It is defined at the household head level and measured in education years.

Contact with extension agents (**Extension_acc**) and the use of other media services such as cell phones (**Own_cell**) makes farmers aware of new technologies and how they can be used (Mwangi and Kariuki, 2015). Thus access to extension services (**Extension_acc)** and ownership of cell phone (**Own_cell)** are expected to have a positive influence on technology adoption in this study. Both variables are measured as dummies, that is, 1 if yes and 0 if otherwise.

The study also includes household economic attributes as important factors influencing the choice of grain storage technologies among smallholder farmers. These are the land size (**PCLandsize**), the value of non-food crops (**PCValuNONFOOD_Crop**), business and wages income (**PCbusiwages_income**), livestock value (**PCLivestock_value**), equipment value (**PCEquip_value**) and vegetable sales income (**PCVegetable_income**). Land size is expected to positively influence the choice of grain storage technologies and is measured in hectares. The land is a productive resource that has a direct effect on output, therefore, households endowed with larger land sizes are more likely to adopt grain storage technologies (Bokusheva et al., 2012; Mwangi and Kariuki, 2015). The access of households to other sources of income such as vegetable sales, non-food crops, and livestock relieve them of financial constraints to adopt new storage technologies (Yehuala et al., 2013), hence are expected to positively influence the choice of grain storage technologies. However, this study argues that farmers who earn wages and have viable business outside farming are less likely to grow maize for storage. Hence, business and wages income is expected to negatively influence the choice of grain storage technologies among smallholder farmers. All the economic variables are measured in per capita value.

3.2.3 Model choice and specification

In agriculture and other fields, choice models are used to represent the choice of one among a set of mutually exclusive alternatives (Okoruwa et al., 2009). Binary logit model, binary probit model, multinomial logit model, multinomial probit model, and nested logit model are commonly used in adoption decision studies involving choices. These discrete response models have been applied in many areas of economics including agricultural economics. For example, Abudulai et al. (2014) used the multinomial logit to model the effects of socioeconomic variables on the influence of choice of three cowpea storage technologies in Ghana. Okoruwa et al. (2009) utilized the multinomial logit method to analyse the post-harvest choices of grain storage techniques and pesticide use by farmers in Nigeria.

Furthermore, these models have been applied in crop choice (Kurukulasuriya and Mendelsohn, 2006), livestock species choice (Seo and Mendelsohn, 2006), and choice of climate adaptation methods (Deressa et al., 2009). Therefore, a multinomial logit model can be suitable for determining the factors influencing smallholder farmers' choice of a particular grain storage technology in Zimbabwe. The study employed a Multinomial logit model to analyse the factors that influence farmers' choice of grain storage technologies. Although both MNL and MNP provide similar parameter estimates, it is computationally easier to estimate MNL to MNP (Abudulai et al., 2014). MNL is appropriate for evaluating unordered combinations of storage technologies that can be unambiguously defined. The study assumes that the choice of a grain storage technology was made from a basket of mutually exclusive grain storage technologies, with Y_i as a random variable denoting the grain storage technology used by a smallholder farmer, and X_i represents socio-economic explanatory variables that can be used to explain the choice of grain storage technology. The relationship between Y_i and X_i can thus be specified as;

$$\text{Pr ob}\,(Y_i = \text{j}) = \frac{e^{\beta' j x_i}}{\sum_{k=1}^{j} e^{\beta' j x_i}},\ \text{j} = 0, 1, 2, 3 \qquad (1)$$

where β_i as is a vector coefficient. Equation (1) is indeterminate and can only be estimated if and only if the equation is normalized by assuming that β_0= 0 (base outcome = 2) such that the corresponding probabilities will be

$$\text{Pr ob}\,(Y_i = \text{j}|X_i) = \frac{e^{\beta' j x_i}}{1+\sum_{k=1}^{j} e^{\beta' j x_i}},\ \text{j} = 0, 1, 3 \qquad (2)$$

Estimating Equation (2) in terms of odds ratio yields;

$$\ln\left[\frac{P_{ij}}{P_{ik}}\right] = X'_i(\beta_j - \beta_k) = X'_i\beta_j \qquad (3)$$

Parameter estimates of the MNL are difficult to interpret and associating the $\beta_i's$ with the j[th] outcome can be misleading and thus inappropriate (Greene, 2003). Thus this study will comment on the signs and significance of parameter estimates as well as estimate the marginal effects based on robust standard errors. Estimation of marginal effects based on robust standard errors is more appropriate (Abudulai et al., 2014) and is given by;

$$\delta_j = \frac{\delta P_j}{\delta X_i} = P_j(\beta_j - \sum_{k=0}^{j} P_k\beta_k) = P_j\,(\beta_j - \bar{\boldsymbol{\beta}}) \qquad (4)$$

It is posited that the signs of the marginal effects may be different from that of the coefficients since the signs of the marginal effects depend on the sign and marginal effects of all other coefficients (Greene, 2003). Empirically, the model is specified as;

$$Y = \beta_0 + \sum_i^n \beta_i X_i + \text{e} \qquad (5)$$

Where:

Y = vector of dependent variable (1 is insecticide technology; 2 is no insecticide technology and is the base category for MNL; 3 is other technologies);

X = vector of exogenous variables;

β = multinomial coefficients;

e_i= error term.

To allow for statistical comparison of the socioeconomic demographic characteristics of the respondents, the observations were categorized into two groups according to the type of storage method (Abudulai et al., 2014). Smallholder farmers who applied insecticide and fumigant tablets to their stored maize grain were classified in the “improved” group while smoking, trap and kill, use of elevated platforms, biological treatment of grain and bagging were considered as traditional storage technologies. Chi-square test (categorical variables) and t-test (continuous variables) were carried out to test for statistical difference between the two groups.

3.2.4 Model diagnostic

Checking for the existence of multicollinearity is important before running the multinomial logit model. Contingency coefficients and multicollinearity (vif) tests were run for the dependent variables accordingly. To detect multicollinearity of continuous variables, the Variance Inflation Factor (VIF) method was used. This states that as R_i^2increases towards one, which is, as the collinearity of regressor X_i with other regressors increases, its variance inflation factor (VIF_i) also increases and in the limit, it can be infinite. Therefore it follows that the larger the value of (VIF_i) the more troublesome or collinear is the variable X_i. According to Gujarati (1995), if the VIF_i of a variable exceeds 10 (this will happen as R_i^2exceeds 0.90), that variable is said to be highly collinear. VIF results are shown in the Appendix B. Likewise, contingency coefficients for dummy variables were computed as follows:

$$C = \sqrt{\frac{\chi}{\eta + \chi 2}} \quad \ldots\ldots\ldots \quad (6)$$

where C is contingency coefficient, χ^2 is chi-square value and n= total sample size. A value of C less than 0.5 or 50% indicates a weak association between the dummy variables (Gujarati, 1995; Maddala, 1992).

3.3 Results and discussion

3.3.1 Descriptive statistics

Descriptive results of the demographic and socioeconomic characteristics of the respondents are presented in Table 3.2 and Table 3.3, respectively. Smallholder farmers who used smoking, trap and kill, use of elevated platforms, biological treatment of grain and bagging were considered as traditional storage technologies.

Table 3.2: Demographic characteristics of respondents

Characteristic	**Total %**	**Improved Technology**	**Traditional Technology**	**p-value**
Male (sex)	61	68	53	***
Married (mar_status)	72	79	63	***
Extension_acc	36	32	40	*
Own_cell	87	88	85	ns

***, **, * Signify statistical significance at 1%, 5% and 10% respectively; **ns** signify not significant.

The results showed that the majority of the farmers interviewed were males (61%) and the proportion of male farmers who used improved storage technologies (68%) was significantly higher than that which stored grain in traditional technologies (53%). Male-headed households are endowed with resources better than their counterparts, hence, they are more likely to adopt new improved storage technologies. Results also indicated that the largest proportion of farmers interviewed were married (72%). Hence a higher percentage of them used improved storage technology (79%) than traditional storage technology (63%). This difference was significant at 1% level. Some 36% of the respondents in the study area reported that they had access to extension services on storage issues. However, a higher proportion of farmers (40%) who used traditional storage technology had access to extension services as compared to their fellow farmers who used improved storage technology (32%). The variance between the two groups was also significant at 10% probability level.

Table 3.3: Socioeconomic characteristics of respondents

Characteristic	Total %/mean	Improved Technology	Traditional Technology	p-value
Educyears	7	8	7	ns
Age	50	50	50	ns
QMZE_harvested	2619	2945	2238	*
TTstored	1543	1782	1263	***
PCValuNONFOOD_Crop	244	316	159	***
PCbusiwages_income	186	172	203	ns
PCLivestock_value	434	453	411	ns
PCLandsize	0.78	0.80	0.76	ns
PCEquip_value	407	425	387	ns

***, **, * Signify statistical significance at 1%, 5% and 10% respectively; **ns** signify not significant.

Household socioeconomic characteristics results (Table 3.3) show that smallholder farmers harvested 2619kg of grain on average. Farmers who used improved storage technology harvested more grain than those who used traditional storage technology. This difference was statistically significant at 10% probability level. In terms of storage, smallholder farmers stored 1543kg of grain, on average. Farmers who used improved storage technology had higher quantities of stored maize grain than their counterparts who used traditional storage technology. This difference was statistically significant at 1% probability level. The monetary value of non-food crops grown by respondents, such as cotton and tobacco, was also significantly different at 1% significance level between smallholder farmers who used improved technology and those who used traditional technology. Consequently, farmers who used the improved storage technology showed higher levels of non-food crops value than their counterparts.

3.3.2 Grain storage technologies among smallholder farmers in Zimbabwe

A categorization of the storage technologies that smallholder farmers use was done to allow for estimation of the factors that influence the choice of storage technology. Three storage categories were identified as shown in Figure 3.1. Categories were defined based on the use of insecticides, non-use of any preservation chemicals and use of biological preservation methods. About 30.22% of farmers did not use insecticide in storage (improved granary, traditional granary, room in the house or poly grain bags) and was considered as the "no insecticide" storage technology. This was identified as the base outcome category. Farmers that used insecticide in the improved granary, traditional granary, room in the house or poly grain bags formed the "insecticide technology". This group constituted 53.96% of the smallholder farmers interviewed. Thus the rest of the farmers who used eucalyptus method, trap and kill, and smoking were categorized as the "other technologies" (15.83%).

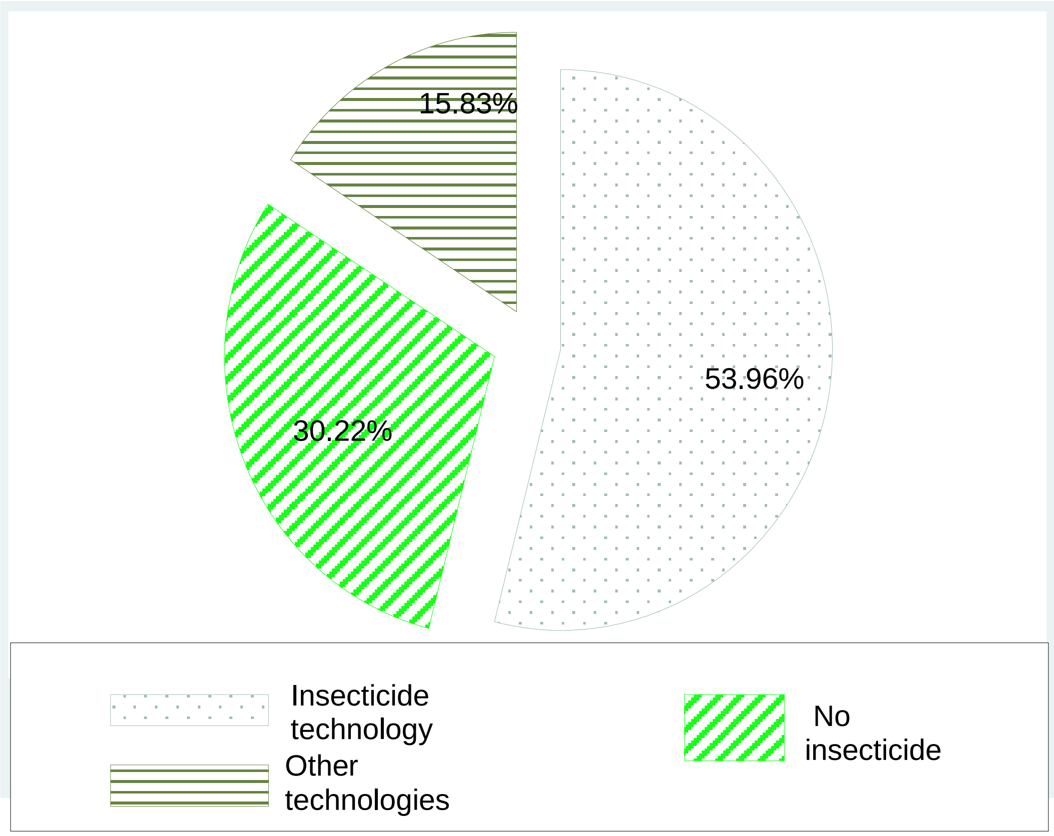

Figure 3.1: Categorization of maize grain storage technologies

3.3.3 Factors influencing choice of grain storage technologies

Multicollinearity tests were done before the model was estimated (Appendix B). The results show no serious correlation problems. A total of thirteen independent variables were used in the MNL model. The MNL results (Table 3.4), show that the age of household head, marital status, total grain stored, per capita value of non-food crop quantity, per capita business and wages income, and extension access influenced the choice of insecticide storage technology relative to no insecticide storage technology among smallholder farmers in the study area. Estimated coefficients for age, marital status, total grain stored and per capita value of non-food crop were positive and statistically significant for the use of insecticide technologies relative to no insecticide technologies. On the other hand, estimated coefficients for per capita business wages and income and extension access were negative and statistically significant in influencing the choice of insecticide technology relative to no insecticide technology.

The results show that education years, total grain stored, per capita business and wages income and access to extension services influenced the choice of other storage technologies relative to no insecticide technologies. The estimated coefficients of education years and total grain stored were positive and statistically significant while estimated coefficients of per capita business and wages income and extension access were negative and also statistically significant in influencing the choice of other storage technologies relative to no insecticide storage technologies.

Table 3.4: Factors influencing choice of storage technology used among smallholder farmers

Variable	Insecticide Technology	Other Technologies
Sex	0.18152^{ns}	0.19446^{ns}
Age	0.01634*	0.01084^{ns}
Mar_status	0.63177*	-0.08001^{ns}
Educyears	0.07452^{ns}	0.14743***
Ttstored	0.00029**	0.00023*
PCValuNONFOOD_Crop	0.00052**	-0.00037^{ns}
PCbusiwages_income	-0.00066**	-0.00057*
PCLivestock_value	-0.00020^{ns}	-0.00036^{ns}
PCLandsize	0.02631^{ns}	0.00284^{ns}
Extension_acc	-0.77778***	-0.72887**
PCVegetable_income	-0.00038^{ns}	-0.00042^{ns}
PCEquip_value	0.00017^{ns}	0.00038^{ns}
Own_cell	0.36822^{ns}	0.84218^{ns}
Constant	-1.71162***	-2.89826***
Base outcome	No insecticide	
Number of observations	417	
Wald chi2 (26)	55.92	
Prob > chi2	0.0006	
Pseudo R2	0.0720	
Log pseudo-likelihood	-381.66577	

*** Significant at 1%, ** significant at 5%, *significant at 10%, **ns** signify not significant

The marginal effects (Table 3.5) implication of these results indicates that the probability of using insecticide technology relative to no insecticide increased by about 16.6% if a farmer was married. In this study area, the majority of smallholder farmers are married and often married couples combine resources and complement each other's efforts towards production and utilization of resources in technology acquisition. Married farmers can also share the related risk of adopting improved storage technologies thus are more flexible in exploring better storage technologies. This result conflicts with the findings of Abudulai et al. (2014), who reported that marital status had no influence on the choice of cowpea storage practices in Ghana.

In terms of storage, a kilogram increase in the total quantity of grain stored increased smallholder farmers' probability of using the insecticide technology relative to the no insecticide storage technology by about 0.005%. This means that farmers who store larger quantities of grain are more likely to use the insecticide storage technologies than those who store smaller quantities of grain. Preservation of stored grain becomes more important with the amount of grain to be stored. Abiodun et al. (2012) reported a similar result where the quantity of maize grain stored significantly influenced the choice of storage technologies among farmers.

More so, the probability of using the insecticide technology relative to the no insecticide technology increases by 0.015% with a US$1 increase in per capita value of non-food crop that smallholder farmers produced. Income from non-food crops improves the financial situation of smallholder farmers thus making them better able to choose appropriate storage technologies. Results from other studies on technology adoption indicate that the non-food crops income has a positive influence on technology adoption (Phiri et al., 2003; Keil et al., 2005).

On the other hand, the probability of using the insecticide technology relative to the no insecticide technology decreased by 0.011% if a farmer had income from business and wages. Business and salaried job activities are alternative sources of livelihood for smallholder farmers, which compete with maize production and thus are negatively correlated with storage. This result corroborates the findings of Kabwe et al. (2009) in Zambia where non-farm income had a statistically significant and negative relationship with technology adoption. Smallholder farmers' access to extension services decreased the probability of using the insecticide technology relative to the no insecticide by 14%. Smallholder farmers in the study areas received extension training on the use of hermetic storage technologies and this could have negatively influenced the role of extension on farmers' preferences of insecticides relative to no insecticide technologies.

Conversely, the marginal effect implication of the education years' coefficient is that a one year increase in education years increases the probability of using the other technologies by about 1.3% relative to the no insecticides technologies among smallholder farmers. This finding met Apriori expectations. Education improves the capabilities of farmers to comprehend and acquire new knowledge and skills required in managing new storage technologies. Therefore the more educated a smallholder farmer is the more able to comprehend and acquire new skills he or she becomes. Similarly, Abiodun et al., (2012); Maonga et al., (2013) and Achiyeng (2014) reported that education significantly influenced the use of improved maize storage technologies among farmers. However, Abudulai et al. (2014) and Fakayode et al. (2014) did not observe any significant relationship between education level and use of cowpea storage technologies in Ghana and Nigeria respectively.

Table 3.5: Marginal effects of factors of choice of storage technology

Variable	**Insecticide Technology**	**Other Technologies**
Sex	0.03032$^{\mathbf{ns}}$	-0.00883$^{\mathbf{ns}}$
Age	0.00307$^{\mathbf{ns}}$	-8.75e-06$^{\mathbf{ns}}$
Mar_status	0.16135**	-0.06675$^{\mathbf{ns}}$
Educyears	0.00543$^{\mathbf{ns}}$	0.01282**
TTstored	0.0000509**	4.92e-06$^{\mathbf{ns}}$
PCValuNONFOOD_Crop	0.00016**	-0.00009$^{\mathbf{ns}}$
PCbusiwages_income	-0.00011*	-0.00002$^{\mathbf{ns}}$
PCLivestock_value	-0.00002$^{\mathbf{ns}}$	-0.00003$^{\mathbf{ns}}$
PCLandsize	0.00622$^{\mathbf{ns}}$	-0.00193$^{\mathbf{ns}}$
Extension_acc	-0.13193**	-0.02927$^{\mathbf{ns}}$
PCEquip_value	7.95e-06$^{\mathbf{ns}}$	0.00004$^{\mathbf{ns}}$
Own_cell	0.03052$^{\mathbf{ns}}$	0.06816$^{\mathbf{ns}}$
PCVegetable_income	-0.000058$^{\mathbf{ns}}$	-0.00002$^{\mathbf{ns}}$
Base outcome	No insecticide	
Number of observations	417	
Wald chi2 (26)	55.9	
Prob > chi2	0.0008	
Pseudo R2	0.0720	
Log pseudo-likelihood	-381.676773	

***significant at 1%, ** significant at 5%, *significant at 10%, **ns** not significant

3.4 Conclusion and policy recommendations

This chapter was directed at finding out the factors that influence smallholder farmers' choice of grain storage technologies in Zimbabwe. Overall, results showed that the majority of smallholder farmers in the area store maize grain in the insecticide technologies, followed by no insecticide technology and lastly, the other technology. Household socioeconomic and demographic factors such as age, education years, marital status, stored grain, the value of non-food crops, business and wage income, and access to extension services significantly influence the choice of grain storage technologies. Older households had higher chances of using the insecticide storage technology indicating that farming experience influences the choice of grain storage technologies. Therefore, the government should target older household heads for promotion and dissemination of storage technologies.

Marital status also increased the chance of using the insecticide storage technology suggesting that married household heads are less risk-averse. Therefore, government and storage technology development agents should target married households for dissemination, without marginalizing unmarried household heads. Furthermore, the total grain stored influenced smallholder farmers to use the insecticide storage technology versus the no insecticide technology. Thus, policies that promote agricultural production will enhance the use of improved storage technologies among smallholder farmers. The government should support agricultural production activities of smallholder farmers. Households with a higher value of non-food crops showed higher chances of using the insecticide storage technology relative to the no insecticide technology. Hence, development agents and the government should develop programs that support the production of non-food crops in smallholder areas without side-lining maize production.

Better-educated smallholder farmers had higher chances of using the storage technology. Government should increase access of farmers to education by developing adult learning programs in the areas. Smallholder farmers with income from business and wage activities showed less likelihood to use the insecticide storage technology. This implies that such smallholder farmers have fewer chances of storing grain hence are more likely not to choose the insecticide storage technology. Farmers who had access to extension services are less likely to use the insecticide storage technology relative to the no insecticide storage technology. The extension training that farmers received on the use and benefits of the new hermetic storage technologies could have influenced them to avoid insecticide storage technologies and choose insecticide-free storage technologies. It could also be that extension workers were not conversant with the new storage technologies hence the training had a negative effect on the choice of storage technologies.

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CHAPTER 4 FACTORS DETERMINING SMALLHOLDER FARMERS' WILLINGNESS TO PAY FOR A METAL SILO IN ZIMBABWE

4.0 Abstract

This chapter examined the factors determining smallholder farmers' WTP for a metal silo in Zimbabwe. Primary data was collected using a structured questionnaire from 249 randomly selected households in Makoni and Shamva districts. The data were analysed using both descriptive and econometric methods. The logit model results showed that household head's age, marital status, non-food crop quantity, equipment value, vegetable income, storage loss and informal activity participation were the key determinants of willingness to pay for a one-tonne metal silo storage technology in Zimbabwe. The results revealed that married respondents and young farmers are more ready to pay for metal silos than their counterparts. While it is recommended that development agents promoting the metal silo technology should target these households for a sustainable approach, care should be taken not to marginalize their counterparts. All the income variables except equipment value showed a positive influence on WTP for a metal silo. This implies that increasing household's income will help to ease the financial constraints that often impede technology investments among smallholder farmers. Therefore, policies that encourage diversification of agriculture and also provision of credit are recommended in order to increase WTP for a metal silo. The amount of grain lost in storage had a positive influence on farmers' WTP for a metal silo. This suggests that current storage practices are not effective against storage losses and therefore the study recommends the government to promote the adoption of improved storage technologies such as the metal silo among farmers in order to curb storage losses and improve household food security. Provision of credit may be highly desirable to increase farmers' WTP.

Keywords: WTP, hermetic metal silo, maize grain storage, logit, Zimbabwe

4.1.Introduction

The outbreak of devastating storage pests such as larger grain borer (LGB) has rendered traditional storage practices of smallholder farmers ineffective (Cugala et al., 2007). These storage pests cause significant post-harvest losses (PHL) of staple crops, particularly maize, in developing countries (World Bank, 2011; Jones et al., 2014). Storage losses of 20-30% are recorded when using traditional storage technologies as a result of storage pests (CIMMYT, 2011; Hodges, 2012). These pests also contaminate produce with trash and foreign materials (Segun et al., 2014). The severe damage caused by pests such as LGB and weevils, common among maize crop, lowers the quantity and quality of the stored grains available for consumption and marketing. At times severe infestation can lead to total grain loss in storage (Stathers et al., 2008; Kamanula et al., 2010; Rugumamu et al., 2011; Segun et al., 2014) therefore contributing to hunger and food insecurity among smallholder farmers. Smallholder farmers thus end up incurring costs to purchase pest control chemicals.

In Zimbabwe, as in other Southern African countries, the maize crop is important for the food supply of the economy. It is a staple crop to over 90% of the population (Zinyengere et al., 2011), constituting 40-50% of the calorie consumed by the poor (Smale et al., 2011), and is also used as animal feed (Kapuya et al., 2011). Smallholder farmers, contribute to more than 50% of national maize production in the country (Chikobvu et al., 2010; Smale et al., 2011). In Zimbabwe, smallholder farmers store about 70% of the maize they produce on the farm for household food consumption (Nyagwaya et al., 2010; Mvumi et al., 2013). More so, 78% of the smallholder farmers store maize in bags, in houses (Mhiko et al., 2014). Maize grain is stored in the shelled form, which then is treated with insecticides, botanical products such as ash and eucalyptus leaves, and or is left untreated (Gadzirayi et al., 2006; Parwada et al., 2012, Muzemu et al., 2013, Mvumi et al., 2013). These storage practices do not offer adequate protection to stored grain causing post-harvest losses estimated at 20 and 30 percent in storage alone (FAO, 2011). Besides, the use of storage pest chemicals can lead to potential environmental and health hazards as the residual effects of the chemicals can be toxic (Adejumo et al., 2014; Hossard et al., 2014). Hence, environmentally friendly and effective storage technologies are required to reduce post-harvest losses, enhance household food security without threatening their health.

The International Maize and Wheat Improvement Centre (CIMMYT), in partnership with the Zimbabwean Ministry of Agriculture, Mechanization, and Irrigation Development, distributed free hermetic metal silo storage technology under a pilot phase to smallholder farmers in the two districts of Shamva and Makoni in Zimbabwe, in 2013. A total of 100 (1 tonne capacity) metal silos were distributed for free to smallholder farmers in each district. The metal silo was chosen for the WTP study because it is the technology that was given to smallholder farmers on a pilot basis and thus already existed in the districts. Hence farmers had an awareness of the technology. Households with a relative surplus production of maize and storage capacity for several months before consumption or sales and in areas where storage pests are perceived as a major problem were targeted for EGSP. The project was funded by the Swedish Agency for Development Cooperation (SDC). The storage technology is new to smallholder farmers. More-so, although its effectiveness against storage pests such as LGB is widely researched (Bravo, 2009; CIMMYT, 2011; Tefera et al., 2011; CIMMYT, 2012; Bern et al., 2013), aspects of affordability and farmers' willingness to pay (WTP) have not been researched in Zimbabwe and region at large. Thus, understanding the factors that influence farmers' WTP for a new storage technology is critical to design appropriate storage technology dissemination programmes and to inform policy. This study, therefore, assesses factors influencing smallholder farmers' WTP for a one-tonne hermetic metal silo.

4.2. Research methodology

4.2.1. Data

This chapter uses primary data collected using methods described in Chapter 2. A total of 249 households from the 417 total samples in two farming districts of Makoni and Shamva were interviewed using a pretested questionnaire. The questionnaire contained a number of modules, some of which were briefly presented in Chapter 2. Modules that are relevant to this chapter include household demographic and socioeconomic characteristics; cropping and harvest; equipment, implements and gadgets; livestock assets, animal products; vegetable production; land ownership, access and use and maize storage pattern and loss assessment. The module capturing metal silo awareness and willingness to pay (non-metal silo users) was specific to this chapter alone. Farmers were asked if they were willing to pay USD$175 for a one-tonne metal silo storage technology. This bid value is the retail price for a one-tonne metal silo as quoted by the supplier of the technology, the Department of Agricultural

Engineering and Technical Services in Harare. The bid value was constant across respondents. Thus the dichotomous single bound question was used to elicit respondents' WTP. The dichotomous question was designed in such a way that respondents gave a YES or NO to their responses. Respondents were selected using a multi-stage sampling procedure and were targeted for CIMMYT's Effective Grain Storage Project (EGSP). The storage project disseminated hermetic storage metal silos to more than 150 households in the two districts in June 2013 on a pilot basis. The survey for this study targeted farmers who had not received metal silos for the pilot study.

4.2.2. Conceptual framework on WTP for storage technology

Studies on a willingness to pay for agricultural storage technology in developing countries are limited. In general, following Aryal et al. (2009), farmers' WTP is a function of knowledge, attitude, and intention. Available information influences both knowledge and attitude toward the proposed technology. Economic models focus on income and the use of the good in question as two important determinants of WTP for a good or service (Liebe, 2011). The argument is that when individuals consider paying for a good (in this case, improved storage technology) their choices and responses to valuation questions are constrained by their disposable income. Thus income is regularly included in stated preference surveys and is expected to positively influence WTP. The theory also suggests that farmers' personal characteristics such as education, age, and gender affect WTP. Theoretically, correlation of educational background and WTP is positive. Therefore a smallholder farmer with more education years has stronger WTP for a storage technology than one with fewer education years. However, the effect of age on WTP can be considered as a combination of farming experience and the planning horizon (International Food Policy Research Institute, 2011). Although longer experience has a positive effect, young farmers may have longer planning horizons and hence more likely to invest in agricultural technologies, in this case, metal silo (Asrat, Belay, and Hamito, 2004; Faye and Deininger, 2005). The effect of age on WTP for a metal silo is thus empirical. Farmers' production characteristics such as land size, and household size, can both positively influence willingness to pay for metal silo storage technology. The two characteristics could better reflect the farmer's production scale and levels (Gang and Ping, 2012). Non-farm income is also expected to have a positive influence on willingness to pay for a technology. According to Holden and Shiferaw (2002), diversification of agriculture enables households to earn income thus easing the liquidity constraint needed for new technology investments. Empirical evidence has revealed that female-headed households are resource constrained compared to male headed households (Mathenge et al., 2010) hence their WTP for a new technology is negative.

Empirically, farmers' WTP for agricultural technology differs across space and time and is influenced by different factors (Gonfa, 2015). Tolera et al. (2014), in a study on factors affecting farmers' WTP for agricultural extension services in Ethiopia, found household characteristics such as household age, exposure to media and family size significantly influencing farmers' WTP using a logit model. Earlier on, Oladele (2008) had examined factors determining farmers' WTP for extension services in Nigeria and gender, educational level, farm size, income and proportion of crops sold were among the factors that influence farmers' WTP, using a probit model. In another study by Abu et al. (2011), off-farm income was also found significantly influencing farmers' WTP for soil management information service. This shows that application of WTP in agriculture has been varied though little or no evidence on storage technology exists, to the knowledge of the author of this study. Therefore, this study seeks to fill this gap in the literature by assessing factors that influence smallholder farmers' willingness to pay for a metal silo in Zimbabwe. However, WTP has its limitations due to its hypothetical nature.

4.3.Selection of variables

4.3.1. Dependent and independent variables

The dependent variable, willingness to pay, is a dummy variable taking on the values of 1 if the household is willing to pay $175 for a one-tonne metal silo and 0 if the household is not willing to pay for it. Farmers are expected to say yes or no when asked for their willingness to pay for the storage technology thus making willingness to pay a discrete variable. Table 4.1 shows the independent variables, measurement, definition and apriori expectations as explained in this study.

Marital status of household head (**marital_status**): Married household heads may share the risks associated with adopting a new technology with their spouses and their production could be higher than unmarried household heads (Maonga et al., 2013). Therefore, married farmers are more likely willing to pay for the new storage technology than their counterparts.

Gender of household head **(gender)**: While male farmers have a better access to production resources such as land than their female counterparts (Sulo et al., 2012), women farmers are expected to be more concerned about household food security than male farmers. Therefore this study expects gender to negatively influence willingness to pay for a metal silo.

Table 4.1: Independent variables of WTP for a metal silo

Variable	**Measurement**	**Definition**	**Expected sign**
marital_status	1=married, 0=otherwise (single, divorced, separated)	Marital status of household head	+
Gender	1=male, 0=female	Gender of household head	-
Informalactivity	1=yes, 0=no	Participation in informal activities that earns income	+
Hhsize	Number	Household size	+
Age	Years	Age of household head	-
Nonfoodcrop_quantity	Kg	Quantity of non-food crops produced	+
EQUIPValue	USD	Value of household productive equipment	+
Landsize	Hectares	Household land size	+
perc_loss	%	Physical grain storage losses	+
Educyears	Years	Household head education years	+
Value_livestock	USD	Value of livestock owned	+
Vegincome	USD	Vegetable sales income	+
ValueANIM_PRODsales	USD	Value of animal product(s) sales	+
Salariedactivity	1=yes, 0=no	Participation in salary or wage-based activities that earn income	+

Participation in informal activity (**informalactivity**): Involvement in informal activities takes away labour from farm operation (Mulugeta, 2009). According to Goodwin et al. (2005), farmers' pursuit of informal income earning activities may undermine their adoption of modern technology as it reduces household labour allocated to farming activities. However, other studies reported that off-farm income acts as a substitute for borrowed capital in rural economies where credit markets are either missing or dysfunctional (Ellis and Freeman, 2004; Diiro, 2013) and hence has a positive influence on technology adoption. Thus the influence of off-farm income in technology adoption, participation in the informal activities **(informalactivity**) is expected to positively influence WTP for a metal silo storage technology among smallholder farmers.This variable is defined as a dummy taking the value 1 if farmers participate in informal activities and 0 otherwise.

Household size (**hhsize**): Household labour is key to the scale or level of agricultural production at farm level (Gang and Ping, 2012). A large family size means the household has labour available for maize production and also the management of the storage technology (Lopes, 2010). Tolera et al.(2014) in his study on factors affecting farmers' WTP for agricultural extension services in Ethiopia found the household size to positively influence WTP. In this study, it is expected that household size will positively influence smallholder farmers' WTP for a metal silo.

Age: The age of household head is defined in years. Its influence on WTP can be considered as a combination of the effect of both farming experience and the planning horizon (Lopes, 2010; Oladele, 2008). This means longer experience by older farmers is more likely to positively influence willingness to pay while younger farmers may have longer planning horizons and hence more likely to invest in agricultural technology. Therefore age is expected to have a positive relationship with WTP for a metal silo.

Education of household head (**educyears**): Education improves the analytical capability of farmers to obtain, process and use information relevant to adoption of new technology (Mignouna et al., 2011; Okunlola et al., 2011). Farmers with more schooling years are highly likely willing to pay for a new storage technology. Education years are used to measure the level of education of smallholder farmers. This hypothesis is supported by other research results (Uematsu and Mishra, 2010).

Non-food crop quantity (**Nonfoodcrop_quantity**): Quantity of non-food crops which are cash crops increases the income potential of the household. Farm activities are the major source of income for rural households, therefore, the more the quantity of non-food crops the more likely the farmer is willing to pay for the new storage technology through the income effect of the non-food crops sold. Maize is a staple food crop which is grown seasonally and its production depends on the weather, thus making storage critical among smallholder farmers. Therefore, even though production of non-food crops may compete against maize production, farmers may still use income from the cash crops to source maize from elsewhere and store it. Thus this study expects a positive relationship between WTP and the quantity of non-food crops.

Equipment value (**EQUIPValue**): Household farm equipment plays a pivotal role in determining the type and scale of production at farm level. Equipment is also a measure of wealth. Productive equipment such as ox-plough, cultivator, scotch-cart, and the tractor was valued in monetary terms. It is thus hypothesized that the higher the value of equipment owned by a smallholder farmer the more likely the farmer is willing to pay for storage technology. Income variables are positively related to willingness to pay (Liebe et al., 2011).

This also follows that income from vegetable sales (**vegincome**), the value of livestock (**Value_livestock**), the value of animal products sold **(ValueANIM_PRODsales)** and smallholders' participation in salaried activities (**Salariedactivity**) are likely to positively influence willingness to pay for a metal silo, all being income variables. Edrias (2003) found that livestock holding has a positive influence on adoption of improved agricultural technologies. This is explained by the fact that livestock holding is an important indicator of households' wealth position and thus is an important source of income which enables farmers to invest in improved agricultural technologies. The same can be said of income from vegetable sales, animal product sales and salary or wage-based activities. They all contribute to household income and can be used to purchase maize production inputs thus increasing maize output hence increased demand for storage technology. Therefore, it is expected that smallholder farmers who have access to income from these four sources have a higher chance of willingness to pay for a metal silo storage technology.

Land size (**landsize**): Land is a principal production factor of smallholder farmers. All other factors being held constant, the bigger the land size the more output is realized. Both theory and empirical evidence point to the positive influence of land size on adoption of technology (Bocquého et al., 2011; Gang and Ping, 2012). Therefore, land size has a positive relationship with WTP for a metal silo technology.

Storage loss (%) (**perc_loss**): Storage loss of maize grain reduces the amount of food available for household consumption and also for sale (Tefera, 2012; Gitonga et al., 2013). It is measured as a percentage; the physical grain lost in storage to total grain stored in a year multiplied by 100. Accessing improved storage technologies that reduce storage losses among smallholder farmers is considered to be crucial. Therefore, it is expected that storage loss has a positive influence on WTP for a metal silo technology.

4.3.2. Model choice and specification

This study employs both descriptive statistics and the econometric model to analyse factors that influence smallholder farmers' WTP for metal silo storage technology. Descriptive statistics such as means, percentages, and frequency distributions were used. The purpose of descriptive statistics was to get a clear understanding of the influence of socio-economic and demographic characteristics of the respondents on WTP for improved storage technology. These factors were compared and contrasted on the two groups of sample farmers; the willing and non-willing categories and the statistical significance of the variables were tested using chi-square and t-tests for dummy and continuous variables, respectively.

Binary responses are best estimated using either the logit or the probit models (Gujarati, 2008; Greene, 2011). WTP for a metal silo is defined as a discrete binary variable, thus this study employed the logit model to analyse the data of the Contingent valuation method. The two models are similar save for the fatter tails in the logit model that is, the probit curve approaches the axes more quickly than the logistic curve. Therefore the choice of which model to use in empirical work is arbitrary and depends on researcher's competence on the ease of use of the two models. In this study, the logit model has been chosen over its counterpart probit model as results of the two models tend to be very similar. According to Tolera et al. (2014), the model is specified as below (equations 1-6):

$$P_i = \left(\frac{1}{1+e^{-(\alpha+\sum\beta_i X_i)}}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where P_i represents the probability that i[th] smallholder farmer will make a certain choice, in this case willing and non-willing, given the explanatory variables (X_i), e represents the base of natural logarithms, i represents the number of explanatory variables (i=1, 2, 3…m), α_i and β_i are parameters to be estimated. The logistic model can also be written in terms of the odds and log of odds (Hosmer, and Lemeshow, 1989) for easier interpretation of the coefficients. Odds ratio is simply the ratio of the probability of willing to pay (P_i) to the probability that the smallholder farmer would be non-willing to pay (1-P_i). However, P_i is non-linear in both explanatory variables and parameters to be estimated thus creating an estimation problem. But,

$$1- P_i = 1 + e^{-Z^i} \quad (2)$$

therefore the odds ratio becomes:

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i} \quad (3)$$

or

$$\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = \mathrm{e}[\alpha + \sum_{i=1}^{m} \beta_i X_i] \quad (4)$$

We then take the natural logarithms of odds ratio equation (4) to get linearity and this results in the logit model as indicated below:

$$Z_i = L_n \left[\frac{P_i}{1-P_i}\right] = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_m X_m \quad (5)$$

As P goes from 0 to 1, the logit goes from -∞ to ∞ showing that the logits are not so bounded even if the probabilities lie between 0 and 1 (Gujarati, 1995). Taking the disturbance term into account, the logit model becomes;

$$Z_i = \alpha + \sum_{i=1}^{m} \beta_i X_i + \mu_i \quad (6)$$

Thus the study used the above econometric model to determine factors affecting willingness to pay for storage technology. The logit model was run against the potential variables affecting willingness to pay for the metal silo, Table 4.2 and Table 4.3 below. Variables were chosen on theoretical, empirical and data availability basis.

4.3.3. Model diagnostics

Checking for the existence of multicollinearity, omitted variables, and heteroscedasticity before running the logit model is important. Hence contingency coefficients and multicollinearity (vif) among dependent variables tests were run accordingly (Appendix D and Appendix E). To detect multicollinearity of continuous variables, the Variance Inflation Factor (VIF) method was used. This states that as R_i^2 increases towards one, which is, as the collinearity of regressor X_i with other regressors increases, its variance inflation factor (VIF_i) also increases and in the limit, it can be infinite. Therefore it follows that the larger the VIF_i , the more troublesome or collinear is the variable X_i. According to Gujarati (1995), if the VIF_i of a variable exceeds 10 (this will happen as R_i^2 exceeds 0.90), that variable is said to be highly collinear. VIF results are shown in Appendix D.

Likewise, contingency coefficients for dummy variables were computed as follows:

$$C = \sqrt{\frac{\chi}{\eta+\chi^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

where C is contingency coefficient, χ^2 is chi-square value, and n= total sample size. A value of C less than 0.5 or 50% indicates a weak association between the dummy variables (Gujarati, 1995; Maddala, 1992). Appendix E displays these results.

4.4.Results and discussions

4.4.1. Socio-economic characteristics of respondents

Descriptive results of socio-economic and demographic factors of respondents using the chi-square and t-tests are displayed in Tables 4.2 and 4.3. All the dummy variables (Marital status, Gender, Informal activity participation) except salaried activity participation were found to be statistically significantly different between the willing and non-willing groups of farmers in the study area.

The majority of the respondents were married (70%) and the difference in marital status between willing and non-willing farmers was statistically significant ($p<0.01$). Of the farmers willing to pay for a metal silo storage technology, 86% were married while 14% were not. More so, there were more male farmers (57%) than women farmers (43%) in the study area. This gender difference was found to be statistically significant ($p<0.01$) between the willing to pay farmers and the non-willing to pay farmers, for a metal silo. From the farmers who were willing to pay for a metal silo, the majority of them were male farmers (71%) whilst the female farmers dominated the non-willing group (56%).

Furthermore, descriptive results showed that the majority of sampled farmers in the study area (78%) were not participating in informal activities. The difference of this factor between willing farmers and non-willing farmers was found to be statistically significant ($p<0.01$). A higher proportion of farmers not willing to pay for a metal silo (83%) were not participating in any informal activities. On the other hand, among those farmers who said they were willing to pay for a metal silo, 29% of them participated in informal activities.

Table 4.2: Differences of dummy explanatory variables between willing and non-willing households

Variable (%)	**Willing**	**non-willing**	**Total**	**p-value**
Gender:				
Male	71	44	57	***
Female	29	56	43	
Marital status:				
Married	86	56	70	***
Otherwise	14	44	30	
Informalactivity:				
Yes	29	17	22	**
No	71	83	78	
Salariedactivity:				
Yes	23	20	22	ns
No	77	80	78	

***, **, *, ns, signify statistical significance at 1%, 5% and 10% probability levels and not significant respectively

Out of the ten continuous variables tested for mean difference between the willing and non-willing farmers using t-test (Table 4.3), seven of the variables were found to be statistically significant at different probability levels. These variables are age, land size, Nonfoodcrop_quantity, perc_loss, ValueANIM_PRODsales, educyears, and vegincome.

The mean age difference between willing and non-willing farmers was statistically significant ($p<0.01$). Farmers who were willing to pay for a metal silo were younger than their counterparts. On average, the total sample farmers owned 3.3 hectares of cultivatable land. Those farmers who were willing to pay for metal silo had larger sizes of land than their counterparts. The difference in land size between the two groups was also found to be statistically significant ($p<0.01$).

Farmers who were willing to pay for a metal silo produced more non-food crops quantities than their counterparts and this difference was statistically significant ($p<0.01$). In terms of storage losses (perc_loss) total sample farmers, non-willing and willing farmers reported losses of 8%, 7%, and 10% respectively. These were reported by farmers. Farmers who incurred lower storage losses were not willing to pay for metal silo than those who incurred big losses. Results indicate that this difference in storage losses incurred was statistically significant ($p<0.05$).

Education years was also found to be statistically significant ($p<0.01$). Farmers who were willing to pay for a metal silo had more education years than the non-willing farmers. However, on average, farmers had 7 years of education in the study area. Finally, the income from vegetable sales was found to be statistically significantly different ($p<0.05$) between willing and non-willing farmers. Those farmers willing to pay for the technology had higher income from vegetables than the non-willing farmers. Overall, all farmers in the study area earned about $260 from vegetable sales in a year.

Table 4.3: Differences of continuous explanatory variables between willing and non-willing groups

Variable (mean)	**Willing**	**Not willing**	**Total**	***p-value***
Hhsize	6.0	5.8	5.9	**ns**
Age	47	54	51	***
Educyears	8	6	7	***
land size	3.8	2.8	3.3	***
EQUIPValue	2479	1730	2079	**ns**
Nonfoodcrop_quantity	842	259	530	***
perc_loss	10	7	8	**
ValueANIM_PRODsales	575	252	402	**
Vegincome	327	202	260	**
Value_livestock	2011	1573	1777	**ns**

***, **, *, ns, signify statistical significance at 1%, 5%, and 10% probability levels and not significant, respectively

4.4.2. Logit results of WTP for a one-tonne metal silo

The multicollinearity results of Variation Inflation Factors showed no serious problem of correlation among variables hence fourteen variables were fitted in the logit model (Table 4.4). Among the variables included in the analysis, the results showed that marital status, age, vegetable income, informal activity, non-food crop quantity, equipment value, and percent storage loss were statistically significant in influencing the probability of WTP for a one-tonne metal silo storage technology. All the significant variables met the Apriori expectations.

Table 4.4: Logit parameter estimates of factors influencing WTP for a metal silo

Variable	Coefficient	Marginal Effect
Gender	-0.00194	0.00048^{ns}
Educyears	0.01535	0.00382 ^{ns}
Hhsize	-0.05668	-0.01409 ^{ns}
marital_status	1.28292	0.29871***
Age	-0.02366	-0.00588**
Vegincome	0.00077	0.00019*
Informalactivity	0.64751	0.16044*
Salariedactivity	0.38648	0.09628^{ns}
Nonfoodcrop_quantity	0·00060	0.00015***
Value_livestock	0.00007	0.00002 ^{ns}
ValueANIM_PRODsales	0.00018	0.00005^{ns}
EQUIPValue	-0.00007	-0.00002*
Landsize	0.08543	0.02124 ^{ns}
perc_loss	0.02497	0.00621*
Constant	-0.90568	
N	249	
Log Likelihood	-137.769	
Wald Chi-Square value	47.61***	

Source: Model Output. ***, **, *, ns signify significant at 1%, 5%, 10% level and not significant, respectively.

Marital status of the household head showed a positive and significant effect on the probability of WTP for the metal silo ($p<0.01$). The marginal effect value indicated that the probability of WTP for metal silo storage technology for farmers who are married increases by 30%, holding all other factors constant. The result is consistent with the finding of Umar et al. (2014) on the determinants of adoption of improved maize varieties in Nigeria. Married household heads share the risks of investing in new technologies by combining their resources.

As expected, age had a negative and statistically significant influence on the probability of WTP ($p<0.05$). This result is in line with a study done by Gang and Ping (2012) on WTP for information. The younger the smallholder farmer, the stronger the WTP for storage technology. This implies that younger farmers may have longer planning horizons and hence more likely to invest in metal silo storage technology. The marginal effects results indicated that a one year increase in the age of a respondent will reduce the probability of willingness of the farmer to pay for the metal silo by 0.6%, holding all other factors constant.

Vegetable income had a positive and statistically significant effect on probability to be WTP for a metal silo storage technology ($p<0.10$). The marginal effects results show that a dollar increase in vegetable income increases WTP for metal silo storage by 0.02%, all other factors being constant. This shows that vegetable income enables farmers to adopt a new storage innovation. Oladele (2008) found similar results in a study of willingness to pay for extension services in Nigeria. Income was a significant determinant of farmers WTP for extension services.

Participation of smallholder farmers in informal activities had a positive and statistically significant effect on the probability of WTP for a metal silo ($p<0.1$). Informal activities boost farmers' income, therefore, making them more willing to invest in new storage technologies. The result supports findings from Tolera et al. (2014), Abu et al. (2011) and Oladele (2008). Furthermore, the marginal effect shows that the probability of being WTP for the metal silo storage technology for farmers who participated in informal activities increased by 16%, *ceteris paribus*.

The quantity of non-food crops produced by respondents was statistically significant and positively influenced WTP for a metal silo storage technology ($p<0.01$). The result from the logit model shows that the probability of WTP for metal silo increased by 0.01% for a 1kg increase in the quantity of non-food crops produced, *ceteris paribus*. Non-food crops are cash crops, hence they enhance financial capacity of farmers to demand storage technologies. Farmers who produce non-food crops can use the income they get from selling these crops to invest in new storage innovations. This result is in conformity with findings from other studies (IFPRI, 2011; Kong et al., 2014) although they used income from agricultural crops rather than quantity of crops grown. A tonne increase of cash crops produced results in a 15% increase in the probability of WTP for a metal silo.

The value of household equipment had a negative but statistically significant effect on WTP for metal silo storage ($p<0.10$). This implies that households with a higher value of equipment were less likely to adopt the metal silo for grain storage than their counterparts. This result was not expected and it could mean the equipment households own favoured the production of other crops instead of maize grain hence households were less likely WTP for the storage technology. The marginal effects result indicated that the probability of WTP for metal silo decreased by a factor of 0.002% as the value of equipment owned increases by a $1000, ce*teris paribus.*

Another variable that influenced WTP for metal silo is the percentage physical grain storage loss. The amount of physical grain storage loss (%) in the study area directly and significantly influenced WTP for metal silo storage technology ($p<0.1$). The probability of WTP for metal silo increases as the percentage grain storage loss increases because farmers would tend to invest in technologies that reduce or curb storage losses. This probability increased by 0.006 for a one percent grain storage loss. Storage losses reduce the amount of grain available for consumption and also for sale. This result thus supports Bokusheva et al. (2012), who reported that household self-sufficiency in maize is an important factor for explaining farmers' demand for metal silos.

4.5.Conclusion and policy recommendations

The use of traditional storage technologies in the face of mounting post-harvest damage is a common problem in Southern Africa among smallholder farming areas. The outbreak of devastating storage pests such as the larger grain borer has also rendered the available storage technologies ineffective. This study set to empirically analyse factors determining smallholder farmers' WTP for a metal silo storage technology. Household head's age, marital status, non-food crop quantity, equipment value, vegetable income, storage loss and informal activity participation were the key determinants of willingness to pay for a one-tonne metal silo storage technology in Zimbabwe.

The results revealed that married respondents are more ready to pay for metal silos than unmarried respondents, and promotion programs should thus target them to ensure sustainable adoption of the technology. Care should be taken so that programs do not marginalize unmarried farmers from the technology. In addition, the quantity of non-food crops, participation in the informal activities, and vegetable income were significant and have positive influences on WTP for a metal silo. These variables have a potential impact on household income, and thus the significant influence on general WTP. Encouraging diversification of agriculture among smallholder farmers would enable households to earn income, thereby ease the financial constraints that impede technology investments.

Young farmers are more likely to invest in the metal silo storage technology hence the government should target young farmers in programs meant to educate and increase awareness of technology among farmers in the country. Percentage physical grain loss incurred in storage is significant and positively influential of WTP of smallholder farmers for the metal silo storage technology. There is a need for the government to promote the adoption of improved storage technologies such as the metal silo among farmers in order to curb storage losses and improve household food security. Provision of credit may be highly desirable to increase farmers' WTP.

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CHAPTER 5 THE EFFECTS OF GRAIN STORAGE TECHNOLOGIES ON MAIZE MARKETING BEHAVIOUR OF SMALLHOLDER FARMERS IN ZIMBABWE

5.0 Abstract

This chapter investigated the effects of grain storage practices on smallholder farmers' maize marketing behaviour using primary data collected from 413 households in Makoni and Shamva districts. The data was analysed using the ordered probit model and the study results revealed that storage practices had significant effects on the maize marketing behaviour of smallholder farmers. The use of insecticide storage increased the chances of farmers to become net sellers of maize. Using insecticide storage technology reduces the amount of grain that is lost in storage hence farmers are able to preserve the amount of grain available for consumption and also for sale. This implies that safe storage of maize promotes smallholder farmers' net maize selling behaviour thus reducing poverty as farmers realise income from selling maize. This also contributes to improved food security. Investment in safe grain storage technologies is thus a fundamental key policy issue in developing countries and as such government should design storage policies that encourage dissemination and promotion of safe grain storage technologies at the household level. Household head's gender, marital status, quantity harvested, market location, farming systems and district location were other factors that influenced maize marketing decisions of smallholder farmers in Zimbabwe. Results revealed that male farmers and married farmers were more likely to participate in the market as net maize sellers than their counterparts. The study recommends that policies that promote the participation of smallholder farmers in markets should be gender responsive. They should include both men's and women's needs for equitable participation of farmers in output markets. Local markets also promoted net selling behaviour of farmers in the study areas hence the development of local institutions that can reduce transaction costs may be highly desirable. These may include collective action groups like farmer input and output marketing groups. Establishment of more point of sales in farming areas in order to lower transportation costs maybe desirable.

Keywords: Storage practices, net seller, net buyer, autarkic, ordered probit, smallholder farmers

5.1 Introduction

Storage of staple crops such as maize remains important in developing countries for smoothening variable supply against constant demand. Maize production in southern Africa is seasonal as it largely depends on rain-fed agriculture, thus making storage a vital component of the value chain. Maize is the staple crop for the majority of people in the region (Smale et al., 2011) and smallholder farmers are the main producers of the crop. In Zimbabwe, at least 70% of the population directly depends on agriculture for their livelihood (Ministry of Agriculture, 2012) and smallholder farmers contribute about 50% to the national maize production (Rukuni et al., 2006; Kapuya et al., 2010). Of the maize produced in Zimbabwe, about 70% is stored on the farm for household consumption and to meet other needs such as marketing (Mhiko et al., 2014). Storage of maize grain allows farmers to temporarily store it and not to market their produce immediately after harvest when prices are low and then market it when prices are favourable. This behaviour can impact smallholder farmers' incomes, food security and livelihoods. Nevertheless, 20% to 30% of the maize grain stored using the traditional technologies is lost. Cereal losses can be as high as 50% (Nukeine, 2010; Tefera and Abass, 2012; World Bank, 2011). Poor post-harvest management of cereals is one of the major challenges of food security in southern Africa (Tefera, 2012). However, little attention has been paid to the economics of post-harvest losses (PHL) and storage technology in studies on household grain management; in particular, their effect on market participation.

Market participation of smallholder farmers has been considered an important part of the agrarian transformation in developing, low-income countries as agricultural markets provide the opportunity for farm production to contribute to poverty reduction through the cash income realized from sales of farm produce (Eleni, 2009; Obi et al., 2012). It is also a means of ensuring food security and enhanced nutrition (Eleni, 2009). According to Bellemare and Barret (2006), the literature on market participation remains thin in developing countries. Moreover, while a substantial amount of effort has been directed to understanding determinants of smallholder farmers' participation in markets as sellers, there is scant attention to why they participate in markets (Muricho et al., 2015). The majority of studies analysed the continuous decision of market participation intensity, conditional on the discrete market participation decision (Goetz, 1992; Bellamare and Barrett, 2006; Alene et al., 2008; Mathenge et al., 2010), while other studies only analysed the continuous decision of market participation intensity (Omiti et al., 2009; Macharia et al., 2014). Hlongwane et al. (2014) found that gender, farmer's access to credit, marital status, market information and infrastructure are positively significant in affecting the market participation decision of maize farmers in the Limpopo province, South Africa. According to Egbetokun and Omonona (2012), age, marital status, the source of labour, farming experience, and farm size are the major determinants of farmers' participation in the markets, whereas the probability of participating in output markets depends on household size, distance to the nearest marketing channel, price of commodity and sex of the farmer (Onoja et al., 2012).

However, to the best of our knowledge, no study, particularly in Zimbabwe, has looked at factors that influence smallholder farmers to participate in maize grain market as either net buyer, autarkic or net seller. This chapter looks at the effects of grain storage technology on smallholder farmers' market participation decision. This area of study is still new in household grain management and market participation literature. Analysing storage technology and smallholder farmers' participation in different market regimes is critical in designing targeted policy interventions. Therefore, this chapter seeks to fill this gap in the literature. The chapter hypothesizes that storage technologies have a significant effect on grain sales and purchasing behaviour or patterns of smallholder farmers in Zimbabwe.

5.2 Research methodology

5.2.1 Data

Primary data was collected from a sample of 413 households using a structured household questionnaire in face-to-face interviews, as described in Chapter 2. This chapter draws from a number of modules, some of which have been presented briefly in Chapter 2. These include basic household demographics and socioeconomic characteristics; equipment, implements and gadgets; land ownership, access and use; cropping and harvest; investments and ownership of grain handling structures; maize storage patterns and loss assessment; insecticide use and training and information sources. However, specific modules to this chapter were household maize selling behaviour and household maize purchasing behaviour.

5.2.2 Analytical framework and selection of variables

In this study, it is assumed that smallholder farmers choose to participate in the maize market as net buyers, autarkic, or net sellers. The decision to participate in the market is ordinal and trichotomous in nature.

5.2.3 Model choice and specification

This study assumes that market participation is "trichotomous" in nature. The continuous market participation outcome can be partitioned into three distinct categories: net buyers (households whose net sales are negative), autarkic (households whose net sales are equal to zero) and net seller (households whose net sales are positive) households. There is a natural ordering of the categories with the lowest category being net buyers of maize. The dependent variable is therefore categorical and qualitative in nature. Following Greene (2000) and Marenya et al. (2015) ordered probit model is the appropriate theoretical model in such a situation. Households participate in a market regime that maximises their expected utility over their planning horizon. According to Muricho et al. (2015), the participation decision can be represented by the following latent model Y^*_{ji} which describes the i^{th}household's behaviour of participating in market regime j revealed in an ordinal scale (1, 2,…,k):

$$Y^*_{ji} = \beta_j X_{ji} + \varepsilon_{ji} \text{ , } \ldots\ldots \quad (1)$$

where X's are a vector of covariates influencing the j^{th} market participation regime and β's are associated vector of parameters, and ε is the error term that has a standard normal distribution. The household's utility from participating in a given market regime is not observable but the decision to participate is observable. Therefore, household's choice of market regime j can be represented as follows:

$$Y_{ji} = \begin{cases} 1 & if \quad Y^*_{ji} \leq \partial_1 \\ 2 & if \quad \partial_1 < Y^*_{ji} \leq \partial_2 \\ 3 & if \quad \partial_2 < Y^*_{ji} \leq \partial_3 \end{cases} \ldots\ldots \quad (2)$$

where ∂_1, ∂_2 and $\partial_3$are unknown net buying, autarkic and net selling threshold parameters, respectively, for estimation in the model. Including an intercept coefficient in the model normalizes Y^*_{ji} to zero value (Greene, 2011), allowing only k-1 additional parameters to be estimated with X's (Okoye et al., 2010). Empirically, the ordered probit model was estimated as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_n X_{ni} \ldots\ldots (3)$$

Table 5.1 represents the specific regressors for the model.

5.2.4 Determinants of market participation

Determinants of market participation are derived from literature, theory and the nature of data available for analysis. Table 5.1 displays the explanatory variables, their measurement, and definition and Apriori expectations

5.2.5 Dependent variable

Market participation (**market_participation**): The continuous market participation outcome is categorized into three distinct groups: net buyer, autarkic, and net seller. There is a natural ordering of the categories with the lowest category being net buyers of maize. Thus the dependent variable takes values 1, 2, 3.

5.2.6 Independent variables

Gender of household head (**gender**): Male-headed households are more market-oriented than female-headed households. Due to their potential crop production efficiency advantages over their female counterparts (Omiti et al., 2009; Gebremedhin and Jaleta, 2010), male-headed households are thus expected to participate in the market more as net sellers than autarkic and more likely as autarkic than net buyers. Gender is measured as a dummy variable, 1 being male and 0 otherwise.

Marital status (**mar_status**): Being married could mean more people to feed and at the same time availability of labour for the production of maize and hence increased output. On the other hand, married people may share the risks associated with participating in markets hence are more likely to participate in the market as net sellers than as net buyers compared to their counterparts. Therefore, the influence of marital status on market participation decisions is expected to be negative. Marital status was measured as 1 if married and 0 otherwise.

Table 5.1: Explanatory variables for market participation decisions

Variable	Definition	Expected sign
Gender	Gender of household head: 1 = male; 0 = female	+
Marital status	Marital status :1= married ;0 = otherwise	_
Age	Age years	+
Household size	Household size (number)	_
Education	Education years	+
Land size	Land size in hectares	+
Own cell phone	Ownership of a cell phone: 1 = yes; 0 = no	+
Quantity harvested	Total quantity of grain harvested (kgs)	+
Extension access	Extension access: 1 = yes; 0 = no	+
A1	1 = A1; 0 = Otherwise	+
Communal	1 = Communal; 0 = Otherwise	+
Old resettlement	1 = Old resettlement; 0 = Otherwise	+
Insecticide treatment	1 = Insecticide treatment; 0 = Otherwise	+
Other storage practices	1 = Other; 0 = Otherwise	+
Market location	Market location: 1 = local ; 0 = otherwise	+
Storage loss	Storage grain loss: ratio	_
District (Shamva)	District: 1 = Shamva ; 0 = Makoni	_

Age of household head (**age**): Young people tend to participate more in the market for agricultural crops because they are more receptive to new ideas and are less risk averse than the older people (Barret, 2007; Geoffrey et al., 2013). Yet, as farmers get older they could acquire skills and hence produce much and develop skills to participate in the output markets (Tekana and Oledele, 2011; Asfaw et al., 2012). Therefore, it is expected that the effect of age of household head on market participation as either net buyer, autarkic, or net seller is empirical. Age was measured in years.

Household size (**hh_size**): Household size could mean availability of labour needed to produce more maize thus increasing the chances of a household to become a net seller than a net buyer. However, it could also mean that there is pressure to the household to provide food for the household members and hence increasing the chances that households become net buyers of the staple crop instead of being a net seller of it (Muricho et al., 2015). Hence, it is expected to negatively influence market participation behaviour; a bigger household size means the household is more likely to be autarkic than to be a net seller and more likely to be a net buyer than to be autarkic, ceteris paribus. This was measured as the number of people living together in the household.

Education of household head (**educyears**): The number of schooling years were used to measure education of the household head. Education usually is a reflection of human capital and management skills (Muricho et al., 2015). Education enhances the ability to critically analyse, understand and respond to information on markets. It empowers the household head with the marketing skills and knowledge; hence education of household head is expected to influence market participation positively. The more the education, the more likely a household head participates as autarkic than as a net buyer and more likely as a net seller than autarkic.

Land size (**landsize**): Land size was measured as the size of productive land in hectares. Increased land size provides a greater opportunity for surplus production (Mussema et al., 2013). Households with large areas of land for maize production are thus capable of producing enough maize for household consumption as well as for sale. The effect of land size on maize market participation is expected to be positive. Households with large land size are more likely to be autarkic than net buyers and more likely to be net sellers than autarkic.

Quantity harvested (**QMZE_harvested**): this was measured as the quantity of maize harvested in kilograms. The volume of maize output determines the level of marketable surplus (Geoffrey et al., 2013) as well as the amount available for storage. Therefore, the effect of quantity of maize harvested on market participation is expected to be positive.

Households who harvest large quantities of maize are more likely to be autarkic than to be net buyers and more likely to be net sellers than to be autarkic.

Farming sector (**A1**, **Communal**, O**ld resettlement**): Three dummy variables for A1, Communal and Old resettlement were created to study the effect of farming sector on market participation. The study recognizes the heterogeneity nature of the different farming sectors of the smallholder farming households in the different wards. Smallholder farming households in Zimbabwe are comprised of the old resettlement farmers, communal farmers, model A1 farmers (newly resettled farmers through land reform) and small-scale commercial farmers. The different farming sectors depict a diversity of agricultural production and resource endowments of the smallholder farmers (Ndakaza et al., 2016). In order to avoid the dummy variable trap, the small-scale commercial farming sector was used as a benchmark and was left out of the analysis. All the three farming sector represent the major maize producing households in the country thus it is expected that households from these areas will more likely to be autarkic than net buyers and more likely to be net sellers than autarkic.

A categorization of the storage technologies that smallholder farmers use was done to allow for estimation of the influence of storage technology on market participation behaviour. Three storage categories were identified. Categories were defined based on the use of insecticides, non-use of any preservation chemicals and use of biological preservation methods. Farmers who did not use insecticide in storage (improved granary, traditional granary, room in the house or poly grain bags) were considered to belong to the "no insecticide treatment" storage technology. This was identified as the base outcome category and was left out of analysis so as to avoid the dummy variable trap. Farmers that used insecticide in the improved granary, traditional granary, room in the house or poly grain bags formed the "insecticide treatment". Thus the rest of the farmers who used eucalyptus method, trap and kill, and smoking were categorized as the "other storage" group. Given these categories and definitions, storage practices (insecticide treatment, other storage) were hypothesized to be the major determinants of market participation in the study. Storage technology was expected to positively influence market participation of households.

Access to extension services (**extension_acc**) and ownership of a cell phone (**own_cell**): Farmers who have access to extension services are more likely to participate in the market as net sellers (Alene et al., 2008; Siziba et al., 2011). Access to extension equips farmers with market information and enhances their negotiation skills. Besides improving market access of farmers, extension services channelled to the production of maize may also boost output thus increasing the marketable surplus. Cell phones can be used to gather and share market information; hence farmers who own cell phones are more likely to be net sellers than net buyers. It is therefore expected that both access to extension and cell phone ownership will positively influence market participation decisions of farmers in this study. This was measured as a dummy variable: 1 if household head owns a cellphone and 0 otherwise.

Market location (**market location**): The distance travelled to the market influences farmers' market participation decision. Distant markets have higher transaction costs in terms of both travel time and cost of travelling than local markets (Omiti et al., 2009; Martey et al., 2012; Musah et al., 2014) hence it is expected that households will choose to participate in the local markets and sell their maize output at farm-gate. Market location is measured as a dummy variable, taking the value 1 if the market location is local and 0 if otherwise. It is expected to positively influence market participation decisions. Farmers who participate in local markets are more likely to be autarkic than to be net buyers and more likely to be net sellers than to be autarkic.

Storage loss (**percloss**): Storage loss is measured as the physical grain lost while in storage due to microbial activities and other factors. This is expressed as a percentage of the total grain stored in the particular year. Storage loss directly determines the amount of grain left for both consumption and consequently for market purposes. Hence, the storage loss is expected to negatively influence market participation decisions of smallholder households. Famers that incur huge losses are more likely to be autarkic than net sellers and more likely to be net buyers than autarkic.

District location (**Shamva**): Geographical specific characteristics may influence market participation decisions of farmers across locations differently. Participants of this study are drawn from two districts, Makoni and Shamva which are both known for high maize production and have similar rainfall patterns. District was measured as a dummy variable; 1 if Makoni and 0 if Shamva. Shamva district is the base category outcome. The influence of location on market participation is expected to be negative.

5.3 Results and discussions

5.3.1 Household characteristics and market decisions of smallholder farmers

Results of chi-square and one-way analysis of variance (ANOVA) are presented in Table 5.2 and Table 5.3. The findings show that five out of eleven dummy socioeconomic variables of household characteristics were statistically significant with statistically significant p-values (Table 5.2). Statistically significant variables were access to extension, market location, district location, and communal and old resettlement farming systems. This implies that differences in these socioeconomic variables contributed to market decisions that smallholder farmers in the study area adopted. One of the means to increase production and productivity in Zimbabwe is through farmers' access to extension services. However, only 36% of the farmers had access to extension services. A higher percentage of net sellers used extension services (42%) compared to net buyers (16%). In terms of market location for selling and purchasing grain, 74% of the farmers used local markets for their transactions. Communal farmers constituted the highest proportion of farmers in the study areas (42%) while old resettlement and A1 model constituted 34% and 15% of the sampled farmers, respectively. Furthermore, most of the farmers who were net sellers came from old resettlement areas (39%), while the majority of net buyers and autarkic farmers were found in the communal areas (57% and 47%, respectively).

Table 5.2**:** Description of dummy household characteristics by farmer group status

Variable		**Farmer group (%)**		**Total (%)**	**p-value (chi-square)**
	Net Buyer	Autarkic	Net Seller		
Male	46	63	63	61	Ns
Married	76	69	72	72	Ns
Extension access	16	28	42	36	***
Own cell phone	84	87	87	87	Ns
Market location sales (local market)	3	0	83	74	***
A1	16	12	16	15	Ns
Communal	57	47	38	42	**
Old resettlement	19	28	39	34	**
Insecticide treatment	43	52	58	55	Ns
Other storage practices	11	15	16	15	Ns
Shamva (location)	62	54	39	45	***

Source: own study. *, **, ***, ns, signify 10%, 5%, 1% statistical significance levels and not statistically significant, respectively

Shamva district represented 45% of the sampled farmers in the study with net buyers being the majority, followed by the autarkic group and lastly, net sellers. Although gender and marital status were not statistically significantly different across the three market decision groups of farmers, results show that 61% of the farmers were male while 72% were married. ANOVA results (Table 5.3) of household head's age, education years, quantity harvested, and land size indicated a statistically significant difference across the three market decision options farmers took.

Further post-hoc test (Tukey test) showed the specific groups where a statistically significant difference was observed. The average age of farmers is 50 years and this was statistically significant at 5% level of probability. This statistically significant difference ($p<0.01$) was observed between the net sellers, who are the youngest, and the autarkic farmers who are the oldest. The coefficient of education years of household heads was statistically significant ($p<0.1$) across the three market participation decision options of farmers. However, the post-hoc test failed to give statistically significant results. On the other hand, the quantity of maize grain harvested was statistically significant (p<0.05), and the post-hoc test showed that statistically, a significant difference was between the net sellers and net buyers; net sellers and autarkic farmers (p<0.01). Net sellers had the biggest volumes of maize grain harvested, compared to their counterparts. On average, farmers harvested about 2443 kg of maize. Land size difference among smallholder farmers was found to be statistically significant (p<0.05) across the three market decision groups of farmers. On average, each household owned 3.5 hectares of cultivable land, with the net buyers of maize grain being the least land endowed, compared to the autarkic and net sellers. A significant difference in land size owned was observed between the autarkic and the net buyers; net sellers and net buyers at 1% and 5% probability levels, respectively.

Table 5.3: Description of continuous household characteristics by farmer group status

Variable		**Farmer group (mean)**		**Total (mean)**	**F-value (ttest)**	***Post-Hoc Test* Tukey**
	Net Buyer (NB)	Autarkic (A)	Net Seller (NS)			
Age (years)	52	54	48	50	***	NS/A***
Education years	7	7	8	7	*	Ns
Household size	6.3	5.9	5.8	5.8	Ns	
Quantity harvested (kg)	1282	1780	2854	2443	**	NS/NB*; NS/A*
Percent storage loss	8.0	9.2	7.5	8.0	Ns	
Land size	2.2	3.5	3.7	3.5	**	A/NB*; NS/NB**

*, **, ***, ns, signify 10%, 5%, 1% statistical significance levels and not statistically significant, respectively

5.3.2 Smallholder farmers' decisions on market participation

The ordered probit model results of smallholder farmers' market participation behaviour are shown in Table 5.4. The chi-square statistics is highly significant (p=0.0000) indicating that the choice of explanatory variables included in the ordered probit model explained the variation in farmers' market decisions. Variance Inflation Factor (VIF) and correlation results showed no serious problem of multicollinearity among explanatory variables (Appendix F and Appendix G). Apriori expectations on the relationship between the dependent categorical variable and the explanatory variables were met.

The estimated coefficients of the ordered probit model provide limited information about the marginal effects of the independent variables on the probabilities of market participation outcome; hence the discussion of results is focused on marginal effects of variables that had statistically significant coefficients. These are presented in Table 5.4. The results of ordered probit model showed that most of the independent variables had a statistically significant influence on the market participation decision options. These variables were insecticide storage, district location (Shamva), gender, marital status, market location, the quantity of maize harvested, and Al, Communal and Old resettlement farming sectors. Insecticide treatment storage showed a positive and statistically significant (p=0.05) influence on the market participation decisions of farmers in the study area. Preserving maize grain in storage with insecticides influenced farming households to be net maize sellers than to be autarkic or net maize buyers, *ceteris paribus*. Insecticides reduce microbial activity in stored grain that cause grain loss, thereby preserving the available grain. Therefore, farmers who use insecticide storage are better placed in the market as net sellers compared to their counterparts who use no preservatives. The results of the marginal effects show that insecticide storage increased the probability of farming households to be net maize sellers by 6% while reducing the probability of being a net buyer and autarkic in the maize market by 5% and 1%, respectively. This result corresponds with the findings of Persson (2009) in a study on market participation and poverty of the smallholders on the Ugandan maize market, where access to storage facilities was correlated with a high probability of market participation. Storage practices that promote safe storage of maize grain allow farmers to participate in the market when it is favourable while preserving the amount of grain meant for household consumption thus promoting positive market participation decisions.

Table 5.4: Ordered probit results with marginal effects

Independent variables	**Coefficient estimate**	**standard error**	**Net Buyer dy/dx(1)**	**Autarkic dy/dx(2)**	**Net Seller dy/dx(3)**
insecticide storage	0.47844**	0.19440	-0.05349***	-0.00927ns	0.06276***
Age	-0.00517	0.00653	0.00058^{ns}	0.00010ns	-0.00068^{ns}
Educyears	0.03010	0.03157	-0.00346^{ns}	-0.0006ns	0.00406^{ns}
location (Shamva)	-0.75118***	0.21921	0.08398***	0.01456^{ns}	-0.09854***
Gender	0.45121**	0.20190	-0.05045**	-0.00874^{ns}	0.05919**
mar_status	-0.71400**	0.28981	0.07982**	0.01384^{ns}	-0.09366***
market location	3.25097***	0.45177	-0.36346***	-0.06301^{ns}	0.42647***
extension_acc	0.21957	0.18731	-0.02455^{ns}	-0.00426^{ns}	0.02880^{ns}
hh_size	0.00965	0.03239	-0.00108^{ns}	-0.00019^{ns}	0.00127^{ns}
QMZE_harvested	0.00008*	0.00005	-8.57e-06*	-1.49e-06^{ns}	0.0001*
Perc_loss	-0.00360	0.487	0.00040^{ns}	0.00007^{ns}	-0.00047^{ns}
own_cell	-0.14043	0.23671	0.01570n^{s}	0.00272^{ns}	-0.01842^{ns}
A1	0.86302**	0.35232	-0.09649**	-0.01673^{ns}	0.11321**
Communal	0.73552**	0.29131	-0.08223***	-0.01426^{ns}	0.09649***
Old resettlement	0.89813***	0.27835	-0.10041***	-0.01741^{ns}	0.11782***
Other storage	0.36201	0.22478	-0.04047^{ns}	-0.00702^{ns}	0.04759^{ns}
land size	0.00959	0.02853	-0.00107^{ns}	-0.00019^{ns}	0.00126^{ns}
N	413				
Wald chi2(17)	131.21				
Log pseudo likelihood	-172.09521				

Source: own study. ***; **; *; ns indicate statistical significance at 1%, 5%, 10% level, and not significant, respectively

The coefficient of gender was positive and statistically significant (p=0.05). This suggests that male households were more likely to be net sellers or autarkic compared to being net maize buyers, *ceteris paribus*. This is expected as female-headed households are often resource constrained thereby affecting their production of a marketable surplus and are also more likely to be concerned about securing food for consumption for the family than for sale. The marginal effects indicated that being a male-headed household increased the probability of being a net maize seller by 5.9% while it reduces the probability of being autarkic and a net maize buyer by 1% and 5%, respectively. Thus gender is a significant determinant of maize market participation behaviour of smallholder farmers and this result correspond with the findings of Hlongwane et al . (2014). Hlongwane et al . (2014) found that gender has a positive and significant influence on market participation of maize farmers in South Africa. Contrary to this, Egbetokun et al. (2017) found that gender had a significant but negative influence on market participation of maize farmers in Nigeria.

Marital status of the household head was also statistically significant but had a negative influence on market participation (p=0.1). This implies that married farmers were more likely to be net maize buyers compared to being autarkic or net maize sellers, *ceteris paribus.* Married farmers are more concerned about being self-sufficient and feeding their households than their counterparts. Results of the marginal effects indicate that being married reduces the probability of being a net seller by 9% while increasing the probability of participating in the market as a net buyer and autarkic by 8% and 1%, respectively. Egbetokun et al. (2017) found a similar result in a study on determinants of market participation among maize farmers in Nigeria. Therefore, marital status is a significant determinant of maize market participation decisions of smallholder farmers.

Market location coefficient was positive and its influence on market participation decisions was statistically significant (p = 0.001). Farmers find it easier to sell their maize locally than to transport it to distant markets. This implies that the availability of local markets induces farmers to produce more maize hence their net selling position as compared to distant markets. The lower transaction costs associated with local markets influence farmers to be net maize sellers than to be net buyers. Results of the marginal effects show that local markets increase the probability of being a net seller by 43% while reducing the probability of being autarkic and net buyers of maize by 6% and 36%, respectively. This result is in line with other empirical studies on transaction costs which established that distance is inversely related to the decision to participate in the output markets (Key et al., 2000; Alene et al., 2008). Therefore, development of local markets in smallholder farming areas is one factor that can boost market participation of farmers. Policies that target upgrading of rural roads and other transportation networks are highly recommendable.

The coefficient of the quantity of maize harvested was positive and statistically significant (p=0.1) in influencing market participation decision options of smallholder farmers in the study area. Farming households with higher quantities of maize grain were more likely to participate in the maize market as net sellers than as autarkic or net buyers, *ceteris paribus*. Amount of harvest directly determines the amount of grain available for household consumption as well as a marketable surplus. The average marginal effects result indicate that a unit increase in the amount of maize harvested is likely to increase the probability of a household being a net seller by about 0.0001 while reducing the probability of being a net buyer and autarkic by 8.57 and 1.49, respectively. Thus the quantity of maize harvest is a significant determinant of market participation behaviour of smallholder farmers as noted in other studies (Geoffrey et al., 2013; Muricho et al., 2015). Policies that boost production of maize at the household level are key to promoting participation of smallholder households in maize markets.

All the variables related to the type of farming sector were positive and statistically significantly influenced farmers' market participation decisions options; A1 model (p=0.05), Communal (p=0.05), and old resettlement (p=0.001). The results indicate that farmers from all the three farming sectors were more likely to be autarkic than net buyers and were more likely to be net sellers than autarkic, *ceteris paribus*. Production of maize is higher in these farming sector areas than in the small-scale commercial farming areas, the base outcome category. The marginal effects show that farms located in the A1 model farming sector increase the probability of farming households to be net maize sellers by 11% while reducing the probability of farming households to be autarkic and net buyers by 2% and 10% respectively. Being a communal farming household reduces the probability of being a net maize buyer and autarkic by 8% and 1%, respectively while increasing the probability of being a net maize seller by 10%. Being an old resettlement farming household also increases the probability of being a net maize seller by 12% while reducing the probability of being autarkic and a net maize buyer by 2% and 10%, respectively. The district location dummy (Shamva) variable was negative and statistically significantly (p=0.001) determined farmers' market participation decisions. This implied that farmers from Shamva district were more likely to be autarkic than net sellers and were more likely to be net buyers than autarkic compared to farmers from Makoni district. Location-specific characteristics could have contributed to this difference. The marginal effects results showed that being a farming household from Shamva district reduces the probability of being a net seller by 10% while increasing the probability of being autarkic and a net buyer of maize by 1% and 8%, respectively. District location dummy variables were also found to be a significant determinant of market participation regimes among smallholder maize producers in Kenya (Muricho et al., 2015). It is therefore important to understand the location-specific characteristics of households in order to design targeted policies for the promotion of market participation so as to improve their livelihoods.

5.4 Conclusion and policy recommendation

Farmers participate in staple food crop markets either as net sellers, autarkic or net buyers. These agricultural staple market options provide the opportunity for poverty reduction through incomes realized from maize sales and also contribute to improved food security and enhanced nutrition as farmers buy maize from the market for household consumption needs. This chapter showed the importance of storage technologies, gender, marital status, quantity harvested, market location, farming systems and district location in influencing maize marketing decisions of smallholder farmers in Zimbabwe. Results showed that the use of insecticides in stored grain influenced farmers to become net maize sellers. Investment in safe grain storage technologies is thus a fundamental key policy issue in developing countries and as such government should design storage policies that encourage dissemination and promotion of safe grain storage technologies at the household level. Agricultural extension campaigns should be promoted in the areas to increase awareness of farmers on the use and benefits of insecticides on stored grain.

Male farmers are more likely to participate in the market as net maize sellers than their counterparts who seem to be more concerned about meeting household consumption needs yet markets provide them with an opportunity to improve their livelihoods through grain sales. Policies that promote smallholder farmers market participation should thus be gender responsive and include both men’s and women’s needs for equitable participation of farmers in output markets. Hence policies that promote market participation of smallholder farmers should be designed to meet the needs of both women and men, without marginalizing the women farmers.

On the other hand, results showed that married farmers were more likely to participate in the market as net buyers of maize than their counterparts. Married farmers have bigger families than single farmers hence their production may not be adequate to meet household consumption needs thus they end up buying more than what they sell on the market. Policies that promote the household production of maize should support married farmers to access both input and output markets of staple crops so as to increase their production levels and thus participate in the market as net maize sellers. Care should, however, be taken not to side-line the unmarried farming households.

Market participation behaviour of smallholder farmers was also shown to differ by location, hence, targeted policies to meet specific market needs of farmers should be designed without marginalizing other maize production areas. Local markets also promoted net selling behaviour of farmers in the study areas hence the development of local institutions that can reduce transaction costs may be highly desirable. These may include collective action groups like farmer input and output marketing groups. In addition, the study recommends that effort should be made at upgrading roads and also support the establishment of more point of sales in farming areas in order to lower transportation costs to promote maize marketing in smallholder farming areas. Besides strengthening extension services it is also important to improve accessibility of the insecticides to farmers.

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CHAPTER 6 THE EFFECTS OF GRAIN STORAGE TECHNOLOGIES ON THE HUNGER GAP AMONG SMALLHOLDER FARMERS IN ZIMBABWE

6.0 Abstract

Storage is an integral part of ensuring domestic food supply in smallholder farming systems, yet research on the role of storage practices in influencing household hunger gap is limited. This chapter estimated the effect of storage practices on the presence of household hunger gap and its intensity, focusing on smallholder households who produce maize in rural Zimbabwe. A double-hurdle model analyzed the occurrence of hunger gap and hunger gap intensity among a sample of 413 households randomly selected in Makoni and Shamva Districts. The logit results of hunger gap occurrence showed that traditional storage, land tenure, location and household characteristics of age, household size, gender, marital status, and education years, significantly influenced household hunger gap. Truncated regression model results showed that total grain stored, quantity harvested, location, land size and business and wages income, had a negative and statistically significant effect on hunger gap intensity while marital status and traditional storage positively influenced hunger gap intensity. The study concludes that traditional storage increases hunger gap intensity while total grain stored reduces its intensity. These findings suggest that policymakers should find effective measures to safeguard lives of people by either boosting production or promoting safe storage of maize grain. The government should also develop programs to improve post-harvest knowledge and skills of smallholder farmers.

Keywords: Hunger gap; Storage; Maize; Logit; Truncated regression, smallholder farmers

6.1 Introduction

Maize is one of the three most cultivated cereal crops in the world (Suleiman et al., 2013). According to de Groote et al. (2013), about 10.14 billion metric tons of maize is produced worldwide and Africa accounts for around 7% of the total world production. Two-thirds of the total maize produced in Africa comes from the eastern and southern region (Verheye, 2010; FAOSTAT, 2014). Maize is important for food and nutritional security for millions of people in southern Africa and the developing world at large. The highest maize consumption is in southern Africa with 85kg per capita per year compared to 27kg in East Africa and 25kg in West and Central Africa (Shiferaw et al., 2011). Maize is the most important food staple in southern Africa, where more than two-thirds of it is used as food and only about 18-20% as animal feed (Kapuya et al., 2010). Zimbabwe has an average maize consumption of over 100kg per capita per year, which represents more than 43% of total calories consumed per capita in the country (Shiferaw et al., 2011). This dependence of the majority of the population in the country on maize is a concern for food and nutritional security. Given the diversified uses of maize, it contributes directly to food security and also to poverty reduction through income growth. Although improving staple crop production is essential for increasing food security and reducing poverty, it is recognized that food security challenges go beyond production to post-harvest (Affognon et al., 2015).

Maize has to be stored to ensure constant supply throughout the year, yet significant storage losses incur at the farm level. In Zimbabwe, maize grain storage is critical to the achievement of household food security as at least 70% of the population directly depends on agriculture for their livelihood (Ministry of Agriculture, 2012). It is widely grown by smallholder farmers who contribute about 50% to the national production (Rukuni et al., 2006; Kapuya et al., 2010). Maize production is seasonal as it mainly relies on rain-fed agriculture. Approximately 16% of rural households and almost 1.5million people are food insecure during the peak hunger season between January and March (UNICEF, 2016). According to ZimVac (2016), 42% of the rural population is food insecure during the hunger season. Food insecurity is persistent in Zimbabwe with at least 12% of the rural population experiencing it over the last five years (WFP, 2014). Maize is stored between August and March and households incur losses during this period (WFP, 2014). Households may go for some months with no maize in stock, due to storage losses. Costa (2014) estimated losses to be as high as 60% in maize grains after storing them for 90 days in the traditional storage structures

(Granary/Polypropylene bags) in Uganda. The outbreak of storage pests such as the larger grain borer threatens the household food security in Zimbabwe. Maize insect pests cause significant yield losses and grain quality deterioration (Tefera, 2012). Stored grain is at risk of storage pest infestation and attacks, rodents, and birds. According to Mhiko et al. (2014), about 70% of the maize produced in Zimbabwe is stored on the farm for household consumption and farm level enterprises. Mvumi et al., (2013), indicates that the majority of smallholder farmers in Zimbabwe shell maize grain for storage and also utilize various preservation methods. Grain exposed to pests and other microbial activities deteriorates in quality and quantity, thus reducing the amount of grain available. Therefore, storage is an integral part of ensuring domestic food supply (Thomaga-Chitja et al., 2004). Nevertheless, research on the role of storage practices in influencing household hunger gap and its intensity in the country is limited. Hence, it is important to look at smallholder farmers' storage practices and their impact thereof on hunger gap so as to inform new policy that can develop appropriate interventions to mitigate food insecurity.

6.2 Research methodology

6.2.1 Data

This chapter depends on the same data set as was collected in the previous chapters; 2 and 5. A structured questionnaire was used to collect data from 413 randomly selected households in the two farming districts of Makoni and Shamva. In addition to modules such as household demographic and socioeconomic characteristics; equipment, farm implements and gadgets; land ownership, access and use; cropping and harvest; insecticide use, maize storage patterns and loss assessment and salaried/business activities the questionnaire asked about sufficiency of own maize harvest for household consumption. Households were asked questions about which months they had run out of maize from their own 2012/2013 harvest.

6.2.2 Conceptual framework and selection of variables

Food security has been defined as a situation when all people, at all times, have physical and economic access to sufficient, safe and nutritious food needed to maintain a healthy and active life (FAO, 1996). This definition implies that food security is a broad concept that is more than food production and food accessibility (Babatunde et al., 2008). It revolves around the four pillars, namely, food availability, food accessibility, food utilization, and stability of food supply (Babatunde et al., 2008; Gebre, 2012; Guja, 2012; Tefera and Tefera, 2014). Food availability refers to the physical existence of food which may come from own production, purchase from markets or from a transfer. Whilst physical availability of food is desirable, it is more important to ensure that food is accessible by individuals or households. Generally, adequate food utilization is realized when food is properly processed and also if proper storage techniques are employed (Tefera and Tefera, 2014). "At all times" introduces a stability dimension, which points to the need for understanding both current and future food security status at different times. Storage ensures maize availability throughout the year and bridges seasons thus contributing to the stability of food security. Thus analysis of food security must capture the temporal dynamics. It is thus important to understand household hunger gap by looking at the availability of maize grain throughout the storage season.

Several studies have looked at the determinants of food security in varying contexts (urban/rural), and levels (regional, national, local) using different variables and methodologies (Muhoyi et al., 2014). Some studies focused on household socioeconomic characteristics such as the age of household head, household size, education years, the gender of household head, and marital status as the main drivers of food insecurity (Sikwela, 2008; Obayetu, 2010; Gebre, 2012; Ngongi, 2013; Muhoyi et al., 2014). Other studies point out that access to extension services, land size, livestock, and off-farm income are key factors to achieving household food security (Amaza et al., 2009; Makombe et al., 2010; Matchaya and Chilonda, 2012). Sikwela (2008) singled out aggregate production, fertilizer, cattle ownership and access to irrigation as key factors in achieving household food security. Muhoyi et al.(2014) and Muzah (2015) looked at household food security in rural and peri-urban areas in Zimbabwe, respectively. Muhoyi et al. (2014), used the logit regression model to examine the determinants of household food security in Murehwa district where household size, farm size, land quality, climatic adaptation, livestock ownership were found to be significant. Ordered probit and Tobit regression models were used in Muzah (2015) to assess determinants of household food security.

The above review highlights that determinants of food security vary across areas with some of the attributes common and also location specific. Little attention has been directed at the role that storage practices play in ensuring household food security. This study brings out important issues in storage technology and food security as it looks at the effects of various storage practices used by smallholder farmers on the household hunger gap. The study not only looks at the occurrence of hunger gap but also at the intensity of hunger gap among smallholder households. In the first stage of the model, the measure of hunger gap is a binary response variable. Farmers were asked to report the month in which they ran out of grain from storage, in the preceding storage year. From this response, the number of months a household went through without grain in storage measured hunger gap. A non-zero positive number of months entailed the existence of hunger gap in the household whereas zero months meant no hunger gap. The study defined hunger gap as 1 if it occurs and 0 otherwise. Other researchers also utilized a binary variable to measure food security at the household level (Oluwatayo, 2008; Guja, 2012; Matchaya and Chilonda, 2012; Tefera and Tefera, 2014; Muhoyi et al., 2014). The second part of the study model looks at the determinants of the intensity of household hunger gap. Hunger gap is measured as a continuous variable with a minimum value of zero months and the maximum value of twelve months. Table 6.1 outlines explanatory variables hypothesized to determine both household hunger gap and the intensity of hunger gap in the study.

This study employs dummy variables to measure the effect of storage practices (**storage_practices**) on household hunger gap and as well as hunger gap intensity. The dummy variables are developed from the three common storage practices that smallholder farmers utilize in the study areas. Definition of storage categories was done based on whether the farmer used insecticides, pesticidal plant extracts or farmer applied no preservatives to the stored shelled grain maize. Farmers who used insecticides and fumigant tablets were categorized as the "insecticide treatment" group. Those farmers who used preservation methods such as smoking, trap and kill, and pesticidal plant extracts, were categorized into the "Other" group. The remaining farmers who applied no preservatives to the stored grain make up the "No treatment" category, which is also used as an indicator for traditional storage. Two dummy variables, Insecticide treatment, and No treatment were used with the "Other" storage practice as the reference group. Overall, this study argues that storage practices play a vital role in ensuring safe storage of grain throughout the storage period and hence are likely to positively impact on both household hunger gap and intensity of hunger gap.

Table 6.1: Independent variables included in the hunger gap and hunger gap intensity regressions

Variable	Measurement	Hunger gap	Hunger gap intensity
Ttstored	Total grain stored(kg)	-	-
perc_loss	Storage grain loss: ratio	+	+
Landsize	Land size in hectares	-	-
Gender	Gender of household head: 1=male; 0=female	-	Excluded
mar_status	Marital status :1=married ;0=otherwise	-	-
Age	Age years	+/-	+/-
Educyears	Education years	-	-
hh_size	Household size (number)	-	+
own_cell	Ownership of a cell phone: 1=yes; 0=no	-	-
QMZE_harvested	Total quantity of grain harvested (kgs)	-	-
extension_acc	Extension access: 1=yes; 0= no	-	Excluded
Busiwagesinc	Income from business and wages (USD$)	-	-
Dist	District: 1=Shamva ; 0= Makoni	+/-	+/-
Land_tenure	Land_tenure[a] 1=Communal; 0=Otherwise 1=A1; 0=Otherwise 1=Old resettlement; 0= Otherwise	+/-	+/-
storage_practices	Storage practices 1=Insecticide treatment; 0= Otherwise 1=No treatment; 0= Otherwise	-	-

[a-]Small Scale Commercial (SCF) is the reference category, [b] other storage practices is the reference category

In this chapter, the efficacy of storage practices is hypothesized as an important determinant of household hunger gap as well as its intensity. The efficacy of storage practices is measured as the percentage grain storage loss (**perc_loss**) incurred in storage. The chapter hypothesizes that storage losses increase the likelihood of the occurrence of the hunger gap and is positively related to its intensity. The study utilizes the farmers' self-reported storage loss figures to determine the storage loss variable. A ratio of the total grain loss in storage as reported by the farmer to the total amount of grain stored at harvest depicts the storage loss (%) (**perc_loss**) variable for analysis.

Furthermore, the study postulates that household socio-economic factors and resource endowments are key factors that impact household hunger gap and its intensity (Kidane et al., 2005; Amaza et al., 2009; Gebre, 2012; Matchaya and Chilonda, 2012; Guja, 2012; Brown, 2013; Tefera and Tefera, 2014). Land size (**landsize**) denotes the total land available for food production that is measured in hectares. Leasing land in return for food or money may increase household income thus enhancing access to food (Muhoyi et al., 2014). On the other hand, Brown (2013) points out that land size determines the quantity of crop production, hence, the larger the land size, the more crop is harvested. Increased crop output leads to increased chances of storage, hence the less likelihood of hunger gap occurring. On the other hand, increased output means fewer months of no grain in storage hence reducing the intensity of household hunger gap. Thus the study expects a negative effect of land size on household hunger gap occurrence and its intensity.

Gender of household head (**gender**) is a dummy variable that takes the value of 1 if household head is male and 0 if otherwise. Women in Africa lack access to resources like land, inputs and support services thereby limiting their capacity to adopt improved farming knowledge and storage practices (Matchaya and Chilonda, 2012). In addition to this, though women farmers may have superior managerial skills as noted in Chavas et al. (2005), their participation in other household responsibilities like child care, household maintenance, and economic production often burdens them. Hence, the study expects gender to negatively affect hunger gap. However, this study did not expect the intensity of hunger gap to be affected by gender, thus gender was dropped out of analysis in the second stage model.

Marital status (**mar_status**) of the household head was measured as a dummy variable: household head takes the value 1 if married and 0 otherwise. Married household heads are more likely to constitute a big number of people to feed. On the other side, married household heads may share the risks that may come with new production and storage opportunities thereby increasing crop output through use of improved farming practices. Hence, being married reduces the likelihood of hunger gap and also reduces its intensity if it occurs. The study expects that marital status negatively affects household hunger gap and hunger gap intensity.

Age (**age**) of the household head is a continuous variable that is measured in years. Older household heads are more likely to experience hunger gap because they are less likely to be productive and more likely to depend on remittances and gifts (Gebre, 2012). On the other hand, remittances allow a household to use chemicals, to have a diverse food base, thus less food gap intensity. Muhoyi et al. (2014) argue that age is an indicator of experience in agricultural production. Therefore the effect of age on household hunger gap and also on the intensity of it is negative in this study.

Farmers with more education years (**educyears**) are more likely to have access to inputs and output prices, new interventions in grain storage as well as other key farming information through the media, for example, newspapers and other sources that may not be available to the less educated farmers (Matchaya and Chilonda, 2012). Education years determines the rational thinking and occupations of individual household heads, thus exposes household heads to other non-farm income earning activities thereby increasing household's ability to access food from the market. Education years is expected to negatively impact both hunger gap and its intensity among households.

Household size (**hh_size**) is the total number of persons living at the same homestead and eating food prepared from the same pot, daily. Larger household sizes constraint the household's consumption budget. According to Sikwela (2008), larger household sizes negatively impact on household food security. A household with a larger household size is more likely to incur hunger gap than one with a smaller household size. This also follows that intensity of hunger gap increases with increase in household size. This study expects to get a similar result on household hunger gap and household hunger gap intensity.

Household head cell phone ownership (**own_cell**) is important in accessing agricultural related information (Matchaya and Chilonda, 2012). Owning a cell phone makes the farmer more aware of the issues in farming and storage. The study expects cell phone ownership (**own_cell**) to negatively relate to household hunger gap and household hunger gap intensity.

The study further postulates that the total quantity of harvested maize grain (**QMZE_harvested**) affects the household hunger gap and hunger gap intensity in line with the literature on household food security (Kidane, 2005; Sikwela, 2008; Khan and Gill, 2009). In Zimbabwe, smallholder farmers rely mostly on maize grain from own production to meet household dietary needs. Therefore, the study expects hunger gap to occur among households with a small production of maize compared to others and its intensity to increase as maize output is decreased. The total quantity of stored maize (**ttstored**), measured in kgs, is a continuous variable that the study also hypothesizes to affect the occurrence and intensity of household hunger gap. The greater the total quantity of grain stored the better the chances of the household to avoid hunger gap and experience a reduced intensity of hunger gap in a typical year, holding all other factors constant.

Access to extension services (**extension_acc)** is a dummy variable that takes the value 1 if household head was trained on the application of insecticides on stored grain and 0 if otherwise. Muhoyi et al. (2014) noted that the availability of extension services to farmers is a key factor in achieving household food security. Farmers with regular extension contact are more likely better informed and equipped in terms of agricultural information. Extension agents are an important source of agricultural information in the smallholder areas. Therefore, the study expects access to agricultural extension services to negatively relate to hunger gap. However, access to extension services is assumed not to be an important factor in determining the intensity of household hunger gap. It is, therefore, left out in the second stage model.

Smallholder farmers derive their income from several sources that include crop and livestock sales, wages, salaried labour, small business enterprises, and remittances. Income from wages and businesses (**busiwagesinc**) helps farmers to diversify and stabilize their incomes, at the same time may provide capital for investment in technology and purchase of critical farming inputs (Jayne et al., 1994 in Muhoyi et al., 2014). Households with more income from businesses and wages are highly likely not to incur hunger gap and if they do, the intensity is lower than their counterparts. The study postulates that business and wages income negatively impact on household hunger gap and its intensity.

Finally, the study uses a district (**dist**) dummy variable to capture the location variations in political, social and agronomic factors of the two study areas and their effect on hunger gap and hunger gap intensity. Shamva district was chosen as the base category because smallholder maize farming is more predominant than in Makoni district. Sinyolo (2016), in a study carried out in South Africa, uses a district dummy variable to capture the effect of location-specific factors. Therefore, the expected impact of the district on hunger gap and its intensity is positive.

On the other hand, the study recognizes the heterogeneity nature of the land tenure of the smallholder farming households in the different wards. Smallholder farming households in Zimbabwe are comprised of the old resettlement farmers, communal farmers, model A1 farmers (newly resettled farmers through land reform) and small-scale commercial farmers. The different farming sectors depict a diversity of agricultural production and resource endowments of the smallholder farmers (Ndakaza et al., 2016). Therefore, land tenure (**land_tenure**) is captured as a dummy variable, with small-scale commercial as the reference category. The effect of land tenure on hunger gap and hunger gap intensity is expected to be negative.

6.2.3 Model choice and specification

This chapter attempts to estimate the effect of storage practices on household hunger gap and its intensity, focusing on households who produce maize in rural Zimbabwe. Hunger gap is only observed for a subset of the sampled population because households who did not experience hunger gap reported zero months of hunger gap, thus the hunger gap intensity function estimated on the selected sample may not estimate the population function (random sample) due to self-selection problems. Thus estimating the parameters by least squares would lead to biased and inconsistent parameter estimates (Wooldridge, 2009). However, there are at least three alternatives to least squares to estimate unbiased, consistent and efficient parameters. The parameters may be estimated using the standard Heckman sample selection model (two-step version) used by Goetz (1992), Benfica et al. (2006), and Boughton et al. (2007). Following Heckman two-step approach, a probit binary model of hunger gap occurrence is estimated first; then, in the second stage, a regression of the hunger gap intensity (number of months without grain in storage) is fitted by ordinary least-squares (OLS), conditional on hunger gap occurrence (Woodridge, 2003). To control for selection bias and obtain unbiased, consistent, and efficient estimators using OLS, an inverse mills ratio (IMR) can be derived from the probit model and included as a regressor into the second equation. In this case, the majority of households reported a positive number of months without grain in storage making the Heckman approach less appropriate. Furthermore, Heckman regression is designed for incidental truncation, where the zeros are unobserved values (Ricker-Gilbert et al., 2011). A corner solution model thus becomes more appropriate in this context because, due to market and agronomic conditions, the zeros in the data reflect farmers' optimal choice rather than a missing value (as with Heckman). Other alternatives to least squares, which are both corner solution models, are the Tobit estimator proposed by Tobin (1958) and the double hurdle (DH) proposed by Cragg (1971). The Tobit model could be used to model households' hunger gap occurrence but its major drawback is that it requires hunger gap occurrence and its intensity to be determined by the same process, that is the same variables, making it fairly restrictive(Wooldridge, 2003 and Ricker-Gilbert et al., 2011). More so, in a Tobit model, the partial effects of a particular explanatory variable on the probability that a household incurs hunger gap and in the expected value of the number of hunger gap months, conditional on hunger gap occurrence, have the same signs (Wooldridge, 2008).

The DH model is a more flexible alternative than the Tobit because it allows for the possibility that factors influencing hunger gap occurrence to be different than factors affecting the intensity of hunger gap (Burke, 2009; Ricker-Gilbert et al., 2011). Hence, a DH model as proposed by Cragg (1971) was used in this study. The DH model is designed to analyse instances of an event that may occur or may not occur, and if it occurs, takes on continuous positive values (Tura et al., 2016). The first hurdle estimates the possibility of incurring a hunger gap or not and, conditional on hunger gap occurrence, the second hurdle estimates the number of months without grain in storage(hunger gap intensity). The binary variable, hunger gap, is used to estimate the maximum likelihood estimator (MLE) of the first hurdle and is assumed to follow a logit model. The use of the logit and probit models will depend on whether an assumption is made that the stochastic error term, μ_i follows a logistic distribution or a standard normal distribution, respectively (Wooldridge, 2002). According to Gujarati (1988), it does not matter much which function is used since the logistic and probit formulation are quite comparable and the two models may give the same result. In this study, a logit model is chosen over a probit model because it is simpler and extremely flexible to work with. The functional form of the logit model is specified as follows (Gujarati, 1995; Greene, 2003),

$$P\ (Y_i=1) = \frac{1}{1+e^{-(\beta_0+\beta_i X_i)}} \quad (1)$$

Equation (1) above can be rewritten as,

$$P\ (Y_i=1) = \frac{1}{1+e^{-Z_i}} \quad , \quad (2)$$

where: P (Y_i=1) is the probability that household has hunger gap, Z_i is the function of a vector of n independent variables. Equation (2) is the cumulative distribution function. It follows that if P (Y_i=1) is the probability of experiencing hunger gap, then 1- P (Y_i=1) represents the probability of experiencing zero hunger gap and is expressed as,

$$1\text{- } P\ (Y_i=1) = \frac{1}{1+ e^{Z_i}} \quad , \quad (3)$$

thus, we can write,

$$\frac{P\ (Y_i=1)}{1-\ P\ (Y_i=1)} = e^{Z_i} \quad (4)$$

Equation (4) is simply the odds ratio, the ratio of the probability that a household experiences hunger gap to the probability that it experiences no hunger gap. By taking the natural log of equation (4) we obtain

$$L_i = \ln\frac{P\ (Y_i=1)}{1-\ P\ (Y_i=1)} = Z_i \ , \quad (5)$$

where L_i is the natural logarithm of the odds ratio which is not only linear in the explanatory variable but also in the parameters. Thus introducing the stochastic error term,μ_i the logit model can be written as

$$L_i = \ln\frac{P\ (Y_i=1)}{1-\ P\ (Y_i=1)} = Z_i \ , \quad (6)$$

$$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \mu_i \quad (7)$$

where β_0 is an intercept and β_1 , β_2 , …,β_n are slopes of the equation in the model, and X is a vector of relevant household characteristics as hypothesized in the study. On the other hand, hunger gap intensity, a continuous variable, is assumed to follow a truncated normal distribution. Thus the MLE is obtained by fitting a truncated normal regression model to the number of months without grain in storage (hunger gap intensity) (Cragg, 1971 and Burke, 2009). The difference between the logit and truncated regression model is that in the truncated regression model only a part of the distribution of the outcome variable, hunger gap, is considered for analysis while in logit model, all the observations of the outcome variable are considered. This means that in logit model, the analysis considers those households who incurred a hunger gap as well as those that did not incur a hunger gap, the full sample (413 households) while truncated regression looks at only those households that incurred a hunger gap (281 households). A total of sixteen explanatory variables are used to model hunger gap while 14 explanatory variables are used in the hunger gap intensity model, as outlined in Table 6.1.

Before running the models, all the hypothesized explanatory variables were checked for the existence of multicollinearity problem. Variance Inflation Factor (VIF) and contingency coefficients for association among the continuous and dummy variables respectively are often the two measures used to test the existence of multicollinearity. In this study, these two were used accordingly (Appendix H and Appendix I). According to Maddala (1992), VIF can be defined as:

$$VIF(x_i) = \frac{1}{1-R^2} \qquad (8)$$

Where R is the squared multiple correlation coefficients between x_i and the other explanatory variables. The larger the value of VIF, the more troublesome it is. As Ri^2 exceeds 0.95, that variable is said to be highly collinear (Gujarati, 1995). Similarly, contingency coefficients for dummy variables will be calculated as:

$$CC=\sqrt{\frac{x^2}{n+x^2}} \qquad (9)$$

Where CC is contingency coefficient, x^2 =chi-square value and n =total sample size

6.3 Results and discussion

The first section presents the means, frequencies, proportions and the inferential statistics of household socio-economic characteristics against the household hunger gap. Descriptive statistics used the t-test and chi-square test for analysing continuous and categorical variables of household characteristics, respectively (Table 6.2 and Table 6.3).

6.3.1 Household demographic and socio-economic characteristics

Table 6.2 presents the t-test means and inferential statistics of the continuous variables, while Table 6.3 presents the frequencies, proportions and chi-square statistics of categorical variables used in the study. The average age of household heads (**age**) was 50. This shows that smallholder farming households are headed by a middle-aged population. Middle aged population may encourage the use of improved farming skills and adoption of new storage technology that reduce storage losses thus reducing occurrence of hunger gap among smallholder farmers. Households had on the average family size of 5.8. This figure is above the average household size of 4.4 people reported by ZIMSTAT (2013). ZimVAC (2014) reported a mean household size of 5.4. Hence, this result implies an upward trend in family size growth. Mutangadura (2000) points that average household size in rural areas is 5.4, thus making this result fairly comparable. The average number of schooling years of 7.5 depicts low levels of education (**educyears**) among the household heads. Literacy rates have declined in the country due to the economic hardships of 2000-2008 (ZIMSTAT, 2013). Low educational attainment may discourage the use and adoption of new improved farming skills and storage technologies in the study areas thus increasing hunger gap. Farmers had access to about 3.5 ha of cultivable land (**landsize**), on average. The size of the land owned is larger compared to the urban and peri-urban households' average of 1.69ha (Muzah, 2015). Land is an important agricultural resource input for the general welfare of smallholder households.

Table 6.2: Description and means of continuous variables

Variable	**TOTAL (**mean=3.3 **)**		**Hunger Gap** (mean= 4.7)		**No Hunger Gap (**mean=0**)**		***p-value (ttest)***
	Mean	S.D	Mean	S.D	Mean	S.D	
age (**years**)	50	16	49	16	51	15	0.4215^{ns}
hh_size (**number**)	5.8	2.7	6.0	2.9	5.5	2.4	0.0568*
educyears (**schooling years**)	7.5	3.3	7.4	3.3	7.5	3.3	0.7000^{ns}
landsize (**ha**)	3.5	2.7	3.3	2.4	3.8	3.1	0.0629**
busiwagesinc (**USD$**)	870	2091	753	1838	1118	2537	0.0976*
percloss (**%**)	8	13	9	14	5	9	0.0022***
ttstored (**kg**)	1555	1972	1430	1725	1825	2400	0.0575**
QMZE_harvested (**kg**)	2435	4187	2147	3350	3049	5532	0.0410**

Source: Own study. ns, *, **, *** signify not significant, 10%, 5%, 1% significance levels respectively.

Table 6.2 highlights that smallholder households had access to other non-farm income sources such as businesses and salaried activities. On average, households earned USD$870 from business and wages (**busiwagesinc**) in a year. According to ZimVAC (2014), casual labour was cited as the most common household cash income source. Diversification of income sources could mean stable income among smallholder farmers. Smallholder farmers can use the income from businesses and wages to buy maize from the local market thus reducing their hunger gap. More so, income from the business and wages can be used to purchase maize production inputs thus increasing maize output for storage and hence reduce hunger gap. In terms of storage losses, smallholder farmers in the surveyed areas reported that they lost grain in storage. Table 6.2 shows that 8% physical storage loss (**percloss**) occurred in storage. Other studies have estimated storage losses to be between 20-30% on average, in sub-Saharan Africa (Nukeine, 2010; World Bank, 2011; Tefera and Abass, 2012). Losses have been attributed to poor post-harvest management of grains (FAO, 2010). On average, smallholder farmers stored (**ttstored**) 1556 kg of maize grain, from a mean harvest (**QMZE_harvested**) of 2435 kg. The mean harvest is above the national mean of 485kg reported in the ZimVAC 2014 assessment. This is expected since the study is in areas that experience good rainfall distribution.

Regarding household demographics (Table 6.3), the majority of the interviewed households in the surveyed areas were male-headed (**gender**) (61%). This was similar to proportions reported in the ZimVAC assessments of 2013 and 2014 (ZimVAC, 2014). However, ZIMSTAT (2013) states that 78.8% of people employed in the agricultural sector are female. The prevailing high unemployment rate, which has seen many companies closing and retrenching employees could have contributed to the urban-rural migration of many male workers, thus offsetting the rural female-male balances. In terms of the marital status of household heads (**mar_status**), the results show that 72% of the household heads were married, while the remainder were never married, divorced or widowed. This picture is consistent with findings from the 2014 ZimVAC assessment.

The majority (87%) of the household heads owned a cell phone (**own_cell**). This finding is consistent with the findings of ZIMSTAT and ICF (2012), which states that 62% of household heads in Zimbabwe have a mobile phone. The main storage practices (**storage_practices**) reported in the surveyed areas are insecticide treatment (55%), no treatment (29%), and other (15%). Giga et al. (1991), Dale and Golob (1997) and Benhalima et al. (2004) in Machingura (2014) and Mvumi et al. (2013) pointed insecticidal control of storage pests as the most widely used stored grain pest management practice among smallholder farmers in Africa. Communal farmers constitute the majority of smallholder farmers in Zimbabwe, and the results (**land_tenure**) show a similar pattern: Communal farmers (42%), Old resettlement farmers (34%), A1 farmers (15%), and SCF (9%). About 36% of the farmers received training on the proper use of insecticides on stored grain (**extension_acc**) from the local extension agents in the survey area. The ZimVAC (2014) showed that 53% of the households in rural areas were members of agricultural extension groups.

The occurrence of hunger gap in the study area was also examined against the household heads' gender, marital status, ownership of a cell phone, district, storage practices; farming system and access to extension services (Table 6.3).

Table 6.3**:** Categorical variables of household demographics

Variable	Hunger Gap %=69	No hunger Gap %=31	Total n=405	*p-value*
gender:				
male=1	69	33	61	0.687[ns]
otherwise=0	67	33	39	
mar_status:				
Married	64	36	72	0.009***
Otherwise	78	22	28	
own_cell:				
Yes	67	33	87	0.423[ns]
No	73	27	13	
dist:				
Shamva	77	23	45	0.001***
Makoni	61	39	55	
storage_practices:				
Insecticide	71	29	55	0.001***
No insecticide	56	44	30	
Other	81	19	15	
Farming_sector:				
A1	69	31	15	0.020**
Communal	74	26	42	
Old Resettlement	58	42	34	
SCF	74	26	9	
extension_acc:				
Yes	60	40	36	0.012**
No	72	28	64	

Source: own study. ns,*, **, *** signify not significant, 10%, 5%, and 1% significance level, respectively

Household hunger gap was common among unmarried household heads (78%) and results show a statistically significant difference between the married and single household heads (p<0.01). The difference in location of interviewed farmers was statistically significant

($p<0.01$) in explaining hunger gap among households. Shamva district recorded the highest proportion of farmers (77%) who experienced a hunger gap. The proportional difference in the use of storage practices was statistically significant ($p<0.01$) between households based on hunger gap. The majority of the households used insecticides in storage (55%), while the minority used other storage practices (15%) on stored grain. However, among those who experienced a hunger gap, the majority (81%) used 'other' storage technologies. The differences in the proportions of farmers who used storage practices are statistically significant ($p<0.01$) and households that did not treat their grain with insecticide or used any other preservatives on stored grain had the highest proportion of no hunger gap occurrence(44%). Of the households who incurred hunger gap, the majority of them (74%) are from the communal areas and SCFs areas, while old resettlement farms had the lowest proportion of farmers. On the other hand, the majority of households who did not incur hunger gap are from the old resettlement schemes while the minority is from the small-scale commercial farms and communal areas. This proportional difference between households who incurred hunger gap and their counterparts is statistically significant ($p<0.05$). In terms of access to extension services, the proportional difference between households with a hunger gap and those with zero hunger gap was statistically significant ($p<0.05$). The results indicate that the majority of households (68%) that incurred a hunger gap had no access to extension services.

6.3.2 The impact of grain storage practices and storage losses on hunger gap and hunger gap intensity of smallholder households

Given the nature of the data collected, a logit model was estimated to determine the household socioeconomic characteristics and resource endowments that predict household hunger gap as presented in Table 6.4. The model reports the marginal effects of how a unit change of the average value of the explanatory variables affects the occurrence of hunger gap. Both the contingency coefficients and the Variance Inflation Factor results confirm the absence of multicollinearity among the variables. The results indicate that, collectively, all the estimated coefficients are statistically significant ($p<0.01$). The model results show that percent storage loss, business and wage income, total quantity maize stored, total quantity maize harvested, land size, extension access, ownership of cell phone, insecticide storage practice, and communal farming sector are not statistically significant determinants of household hunger gap (Table 6.4). The rest of the factors were significant and met Apriori expectations.

Table 6.4: Binary logit estimates of hunger gap and truncated regression of hunger gap intensity

Variable	**Logit regression**		**Truncated regression**	
	Coefficient	Marginal effect	Coefficient	Marginal effect
Age	-0.0248694***	-0.0050649***	0.0086003[ns]	0.0086003[ns]
hh_size	0.1286727***	0.0262053***	-0.0341161[ns]	-0.0341161[ns]
Educyears	-0.0812262*	-0.0165424*	0.0021321[ns]	0.0021321[ns]
Landsize	-0.0580135[ns]	-0.0118149[ns]	-0.1104516*	-0.1104516*
Busiwagesinc	-0.0000486[ns]	-9.89e-06[ns]	-0.0001947**	0.0001947**
Perc_loss	0.0170703[ns]	0.0034765[ns]	0.002182[ns]	0.002182[ns]
Ttstored	-0.0000369[ns]	-7.52e-06[ns]	-0.0001672*	-0.0001672*
QMZE_harvested	-0.0000198 [ns]	-4.03e-06[ns]	-0.0001434**	-0.0001434**
Gender	1.112138***	0.255112***	Excluded	
mar_status	-1.830381***	-0.289576***	1.032151**	1.032151**
own_cell	-0.1194552[ns]	-0.019076[ns]	-0.7016299[ns]	-0.7016299[ns]
location dummy	0. 8821045***	0.1742706***	-1.052789**	-1.052789**
A1	-1.522378**	-0.3517798**	-1.045842[ns]	-1.045842[ns]
Communal	-0.6169431[ns]	-0.1278878[ns]	-0.257405[ns]	-0.257405[ns]
Old resettlement	-1.05304**	-0.2257076**	0.1433625[ns]	0.1433625[ns]
Insecticide_treatment	-0.6200422[ns]	-0.1241784*	-0.4941853[ns]	-0.4941853ns
No_treatment	-1.139558***	-0.2489127***	1.280635**	1.280635**
extension_acc	-0.2531388[ns]	-0.070809[ns]	Excluded	
Constant	4.149445***		5.878305***	
N	413		281	
Log likelihood	-221.42816		-612.7531	
LR chi2(18)	74.70***			
Wald chi2(16)	75.40***			

Source: Own study. *, **, *** signify 10%, 5%, 1% significance level, and ns not significant

The no treatment storage compared to the rest of storage practices used in the study area showed a negative and statistically significant relationship with household hunger gap ($p<0.05$). Farmers who did not treat their grain in storage had 25% higher chance of not experiencing hunger gap than their counterparts. This was not expected and could be explained by that these farmers were net buyers of maize and did not store much maize. The logit marginal effects result shows that insecticide treatment storage reduces hunger gap occurrence by 12.4% and statistically significant ($p<0.10$). This is expected. Insecticides reduce pests activity on stored grain that causes losses.

A negative and statistically significant effect of household age on hunger gap was observed ($p<0.01$). Age influences hunger gap. This implies that as household head's age increases by one year, the chances of the household head to experience a hunger gap decreases by 0.05%. This suggests that household head's age impacts positively on household storage decisions and hence food security at household level. This result agrees with Beyene (2010) who suggests that age of the household head has a positive and significant relationship with household food security. Older household heads are more experienced in farming and are also more committed to farming activities compared to young farmers.

It was observed that education years had a negative and significant effect on household hunger gap ($p<0.10$). A unit increase in number of education years reduces the occurrence of hunger gap by 1.7%, *ceteris paribus*. Mutisya et al. (2016) showed a significant and positive relationship between education and household food security in Kenya. The probability of being food insecure decreased by 0.019 for a unit increase in the average years of schooling for a given household.

The results reveal that household size has a positive and statistically significant ($p<0.01$) effect on hunger gap as expected. Household size was found to be statistically significant ($p<0.01$). This means that adding one member to the household increases its chance of experiencing hunger gap by 2.6%. Muhoyi et al. (2014) noted that household size is a statistically significant determinant of household food security in Zimbabwe, showing a negative influence. This means that an increase in household size, *ceteris paribus,* implies more people to be fed from the limited resources.

The model reveals that gender is a statistically significant determinant of hunger gap at the household level ($p<0.01$). Male headed households have a 23% higher chance of experiencing hunger gap than female-headed ones. This result is consistent with Amaza et al. (2008) in their study on measurement and determinants of food insecurity in northeast Nigeria. As reported by Meena (1992), Rugumamu et al. (1997), FAO (2003) and Kingamkono (2006) in Rugumamu (2009), women are mostly responsible for ensuring household food sovereignty and security albeit their inadequate agricultural resources. Creighton and Omari (2000) argued that in smallholder crop production, women are more likely to be socially and economically involved in post-harvest activities than men. More so, Mallick and Rafi (2010) finds that a bigger share of the women's contribution to the household income is spent on food while a bigger share of the men's contribution to the household income is spent on alcohol and tobacco. Therefore, women farmers could be more experienced in handling grain storage management to ensure household food security than male farmers.

A statistically significant negative influence of marital status on household hunger gap was observed ($p<0.01$). This means that married household heads have a 30% higher chance of not experiencing hunger gap than their counterparts. Cancian and Reed (2009) found similar results. Muzah (2015) found that married household heads have a better chance of maintaining household food security as the couple helps each other. On the other hand, unmarried household heads bear a large burden of attaining food as they have limited support structure. The district in which a household resided was observed to have a statistically significant and positive influence on household hunger gap ($p<0.01$). Households in Shamva District show a 17% higher chance of experiencing hunger gap than those in Makoni District. This could be a result of differences in quantity of maize harvested, though both districts are major maize growing districts in the country.

Results show that being an A1 model farmer compared to the rest of the farming sectors in the study area had a negative and statistically significant relationship with hunger gap occurrence ($p<0.05$). This means that an A1 model farmer has a 35% higher chance of not experiencing hunger gap than their counterparts. Likewise, being an old resettlement farmer had a negative and statistically significant relationship with hunger gap occurrence ($p<0.05$). The implication of the result is that a farmer from the old resettlement areas has 23% higher chances of not incurring hunger gap than their counterparts. The different farming sectors depict a diversity of agricultural production and resource endowments of the smallholder farmers (Ndakaza et al., 2016). Farmers in these farming sectors are more likely to produce more maize than the rest of the areas, hence are highly food secure.

From the truncated regression model, marital status, total grain stored, land size, business and wages income, quantity of maize harvested, no treatment storage, and location were the main factors that affected hunger gap intensity. Marital status had a positive and statistically significant influence on hunger gap intensity ($p<0.05$). Being married increases hunger gap intensity by 10%, *ceteris paribus.* Married household heads have larger household sizes compared to unmarried household heads. Total grain stored affects hunger gap intensity. Its effect on hunger gap intensity was negative and statistically significant ($p<0.10$). This implies that as grain stored increases by a kg, hunger gap intensity reduces by 0.002%. This result was expected. Land size also had a negative and statistically significant effect on hunger gap intensity ($p<0.10$). The larger the land size, the less hunger gap intensity a household experiences. A unit increase in land size reduces hunger gap intensity by 11%. Larger land size implies more maize output than smaller land sizes all other things being equal.

Business and wages income had a negative and statistically significant effect on hunger gap intensity ($p<0.05$). A unit increase in business and wages income reduces hunger gap intensity by 0.002%. Income from business and wages helps a household to make food purchases during the lean period thus reducing hunger gap intensity. Furthermore, the quantity of maize harvested showed a negative and statistically significant effect on hunger gap intensity ($p<0.05$). A household that harvests more maize stores for a longer period than its counterpart, thus experiencing less hunger gap intensity. A unit increase in harvested maize reduces hunger gap intensity by 0.001%. Results further indicated that no treatment storage had a positive and significant relationship with hunger gap intensity. Grain that is stored untreated is prone to pests attacks. This results in storage losses hence increased hunger gap intensity. The model results also showed a negative and statistically significant relationship between hunger gap intensity and location ($p<0.05$). Being a household head from Makoni district reduces hunger gap intensity by 11%. This could be a result of differences in location specific factors such as post-harvest handling.

6.4 Conclusion

Results showed that the majority of the households experienced hunger gap. On average households that experienced hunger gap had a hunger gap of 4.7 months. Overall, a hunger gap of 3.2 months was recorded among households. This means that food insecurity is an issue of concern among smallholder farmers. Policy makers should come up with effective measures to safeguard lives of people either by boosting production or promoting safe storage of maize grain.

Several household socio-economic characteristics such as age, household size, gender, marital status, location, education years, and being an A1 model or Old resettlement farmer and no treatment storage significantly influence the occurrence of household hunger gap. Larger household size increased chances of experiencing hunger gap, which suggests the need to implement effective family planning methods to keep the family sizes small. Development agents should provide effective family planning education and training to farmers in the rural areas.

Farmers who had larger sizes of cultivated land showed lower chances of experiencing hunger gap than their counterparts. Therefore increasing smallholder farmers' access to land will alleviate the problem of hunger gap and food insecurity. Households with more years of schooling had lower chances of incurring hunger gap, therefore, the government should develop adult learning programs to increase literacy levels of households in the area and hence reduce hunger gap occurrence.

It was also observed that hunger gap differs by location, farming sector, and storage practices. Farmers in Shamva district showed higher chances of experiencing a hunger gap than those in Makoni district, while farmers in the A1 model and old resettlement schemes had better chances of not incurring it. These farmers have better access to land and other productive resources thus lower chances of incurring hunger gap. Government supported input schemes should target areas where farmers have less access to inputs so as to improve productivity. Farmers who used no treatment on stored grain had better chances of not incurring hunger gap in the study areas. This could be explained by that these farmers were net buyers of maize and did not store much maize. Hence, there is need to investigate the location-specific characteristics of smallholder farmers. The government may also develop programs targeted at improving post-harvest knowledge and skills of smallholder farmers.

Smallholder farmers record significant storage losses which lead to hunger gap. Protecting grain crops from such losses is thus an important step towards ensuring food security. Several factors had a statistically significant influence on the intensity of hunger gap among households. These are marital status, total stored grain, land size, business and wage income, quantity of maize harvested, no treatment storage and location. Larger quantities of stored grain reduced hunger gap intensity thus government should develop policies that promote and enhance grain storage among households. On the other hand, the quantity of maize harvested had a negative effect on hunger gap intensity, therefore, promoting policies that boost household production will reduce hunger gap intensity. The government should also develop programs that equip farmers with proper grain handling skills as no treatment storage had a positive and statistically significant influence on hunger gap intensity. Farmers should be taught on the proper use of grain protection methods to reduce storage losses. Creation of employment opportunities will also reduce hunger gap intensity as business and wages income negatively influenced hunger gap intensity.

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CHAPTER 7 STORAGE LOSSES AMONG SMALLHOLDER FARMERS AND THE ECONOMIC VIABILITY OF MAIZE STORED PRODUCT PROTECTION METHODS IN ZIMBABWE

7.0 Abstract

Smallholder farmers incur significant post-harvest storage losses (PHL). Their reliance on traditional storage practices contains the high risk of exposing their grain to pests, rodents, birds and mold attacks. This chapter estimated and compared the financial profitability of storing one tonne of maize grain in farmers' two storage technologies of actellic (*Pirimiphos-methyl*) treated polypropylene bags and untreated polypropylene bags to two hermetic storage technologies of the metal silos and super grain bags. Using on-station trials storage loss data, resulting from a cost-benefit analysis, showed positive NPVs of both metal silos (USD67.21 and USD74.96) and super grain bags (USD70.26 and USD106.76) versus untreated bags and treated bags respectively. B-C ratios (1.31; 1.38 for the metal silo and 1.28; 1.50 for the super grain bag) of hermetic technologies were also greater than farmers' storage technologies of untreated bags and treated bags respectively. Thus both hermetic technologies were found to be financially viable at an opportunity cost of 15%. Sensitivity analysis results also showed that it would pay for smallholder farmers to invest in both hermetic technologies and the returns would be higher in the long run than in the short run, as hermetic technologies require considerable time to recoup the high initial capital costs, particularly the metal silo storage technology. The chapter concludes that hermetic technologies are effective storage technologies to reduce PHL in Zimbabwe. These findings suggest that policy makers should consider wide dissemination of hermetic technologies, with possibilities for the provision of credit to ease high initial capital costs.

Keywords: Post-harvest, maize grain, hermetic storage technology, Actellic, bag storage, cost benefit analysis

7.1 Introduction

Storage pests cause significant post-harvest losses (PHL) of staple crops, particularly maize in developing countries (World Bank, 2011; Jones et al., 2014). The situation has been worsening since the accidental introduction of *Prostephanus truncatus* or Larger Grain Borer (LGB) in the late 1970s and early 1980s in Eastern and Western Africa, respectively. So far, the pest has spread to more than 18 countries in western, eastern and southern Africa (Cugala et al, 2007). In Zimbabwe, the pest was discovered in the 2006/2007 agricultural season (Mhiko et al., 2014), though it was officially declared in the country in 2010 (Nyagwaya et al, 2010). LGB is known for its destructive feeding habits; it is capable of destroying wooden objects, dry timber and even leather (Stathers et al, 2008).

Storage losses caused by pests range from 20-30% (CIMMYT, 2011; Hodges, 2012) and LGB can cause physical weight losses of 100% (Kamanula et al., 2010; Stathers et al., 2008; Rugumamu et al., 2011) if the grain is not effectively protected. This reduces both grains available for household consumption as well as for marketing. Smallholder farmers are most vulnerable to PHL in sub-Saharan Africa due to the use of traditional storage practices. In southern Africa, smallholder farmers use traditional grain storages made out of different materials for example grass, wood, bricks, mud, jute bags, wooven polypropylene bags. The materials cannot guarantee protection against major storage pests such as LGB and maize weevil. These challenges often force smallholder farmers to sell their produce immediately after harvest when producer prices are low, and only to buy it back at higher prices later in the marketing season (Kimenju et al., 2009; Tefera et al., 2011; Gitonga et al., 2015). This behavior ends up pushing resource limited farmers further into poverty.

The Swedish Agency for Development Cooperation (SDC) implemented a four year project in Zimbabwe starting in 2012 on effective grain storage (EGSP) (http://blog.cimmyt.org/tag/effective-grain-storage-for-sustainable-livelihoods-of-african-farmers-project/). Two hermetic storage technologies, namely, the use of metal silos and super grain bags, were piloted in two districts under smallholder farming (Makoni and Shamva). The main goal of the EGSP-project was to enhance household food security by reducing post-harvest losses and increasing incomes of target farmers through provision of improved stored product protection methods.

Hermetic storage technologies are new to smallholder farmers in Zimbabwe. Though metal silos have been used since the 1980s by SDC in Central America, and are noted for effectively protecting grain against pest and rodents attacks (Tefera et al, 2011; SDC, 2013;), their use and uptake in southern Africa in general, and Zimbabwe in particular, has been limited to demonstrations and pilot activities despite high PHL being recorded throughout the storage season.

Pilot activities particularly those being initiated by CIMMYT in Zimbabwe are meant to increase farmer awareness of the technology and stimulate the technology uptake process. As part of promoting the hermetic technologies among farmers, the EGSP-project also trains local artisans (*tinsmiths*) on metal silo fabrication. The training is meant to give the artisans a decent understanding of the efficacy of inert atmospheres created in the hermetic technologies and hence provide skills necessary to create a gastight metal silo.

About 70% of maize produced in Zimbabwe is stored on the farm by smallholder farmers (Mhiko et al., 2014). On the other hand, smallholder farmers, who contribute more than 50% of national maize production in Zimbabwe, rely on a single harvest of maize, which is also prone to vagaries of nature (Chikobvu et al., 2010; Smale et al., 2011). Effective storage is therefore required in the smallholder farming sector in order to maintain a constant supply of maize grain all year round. Maize is used as a staple crop by over 90% of the population in Zimbabwe (Zinyengere et al., 2011). Besides maintaining a constant supply of maize grain, effective storage is also necessary to preserve the quality of grain until it is required for use (for consumption or sale).

However, evidence on the effectiveness of hermetic storage technologies (Bravo, 2009; CIMMYT, 2011; Tefera et al., 2011; CIMMYT, 2012; Bern et al., 2013) has not been backed by empirical evidence of economic and financial viability in smallholder farming systems of developing countries in southern Africa. Highly effective technology for protection is often expensive and its adoption will be limited unless it is profitable (Jones et al., 2014). Since hermetic storage technologies are relatively new in the country, no studies have been conducted to determine the financial viability of the hermetic storage technologies. Economic analysis of storage technologies particularly, for maize, are also not well documented (Kimenju and de Groote, 2010) and in some instances, these have been promoted without being subjected to economic analysis; forcing farmers to adopt technologies available to them without full information of their performance.

This chapter estimates and compares the viability of four stored product technologies for use by smallholder farmers and therefore identifies the most profitable one. These technologies are the use of metal silos, super grain bags, polypropylene bags treated with Actellic super gold dust and untreated polypropylene bags. The analysis is particularly relevant given that smallholder farmers are faced with several storage choices. More-so evidence about the financial viability of new stored product technologies will lend critical evidence to the government, non-governmental organizations (NGOs) and private interventions in the grain storage industry.

This chapter also compares the quantitative loss of grain in both traditional and hermetic storage technologies using on-station trials storage loss data to inform appropriate policies meant to reduce storage losses among smallholder farmers in Zimbabwe. Simple graphs are used to demonstrate the relationship between storage losses and storage practices, augmenting the cost-benefit analysis technique results of storage profitability which constitute the bulk of the work of this study. Understanding storage losses is also vital as storage losses contribute to high food prices by removing part of the food supply from the market (Tefera, 2012).

The chapter comprises six sections. The first section covers the background and justification, the second section looks at the overview of grain losses in storage among smallholder farmers. The third section focuses on the overview of CBA as the main analytical methodology. Methods of study are presented in the fourth section and the fifth section looks at study findings. Lastly, the sixth section covers conclusions and recommendations of the study.

7.2 Research methodology

7.2.1 On-station trial

This chapter used primary data to compare percentage weight storage losses of smallholder farmers' storage technologies to hermetic storage technologies. Storage loss data from the

CIMMYT/UZ on-station trials on the effectiveness of storage technologies against maize weevil and LGB was collected over ten months between August 2012 and May 2013. The experiment was conducted at two stations; Makoholi Research Station (Natural Region IV), near Masvingo and Hatcliffe (Natural Region II), at the Insitute of Agricultural Engineering (IAE) in Harare. The sites represented the best and worst agro-ecological conditions for smallholder maize farmers in Zimbabwe, therefore the results are nationally representative. The maize grain (variety SC 637) used for the experiment was sourced from IAE and 50 Kg super grain bags (SGBs) were procured from a GrainPro agent in Harare. GrainPro SGB is an Ultra Hermetic bag lining solution developed primarily for smallholder farmers (http://grainpro.com/gpi/index.php?option=com_content&view=article&layout=edit&id=205). It is made up from a multilayer recycled polyethylene plastic and can be reused. Metal silos (100 Kg) were bought from a local general engineering firm while Actellic Super Gold (commercial synthetic pesticide) and 50 Kg woven polypropylene bags were sourced from the local market. Galvanized plain iron sheets were used to fabricate the metal silos. The grain was exposed to the sun before storage and thus was dried to 13.5% moisture.

A Completely Randomised Design (CRD) was used to set up the experiment consisting of four treatments namely; the Metal silo, Super grain bag (SGB), Actellic super gold treated polypropylene bag and untreated polypropylene bag. These treatments were replicated three times under natural and artificial modes of infestation. Under natural infestation, the grain was not disinfested initially and no insect was introduced to each storage structure while, for artificially infested treatments, grain was initially fumigated using Phostoxin® tablets at label rate for seven days to disinfest any possible prior infestations. A mixed adult insect population of *S. zeamais* and *P. truncatus* was then added to each replicate treatment at a ratio of one insect/kg of grain. No pesticides were added to metal silos and SGBs treatments and each replicate were 40kgs to allow easy tying and create a hermetic environment. The air was squeezed out of the SGB and a zipper slider was used to tie the triple bags, thus creating the hermetic environment. The metal silo's outlet lid was also completely closed and tied with a rubber band before loading the grain. Grain was loaded using a bucket to avoid pressing the inlet lid and then two burning candles were placed on metallic candle holders and left to burn out. The inlet lid was then closed with a top cover and completely sealed with a rubber band. The assumption is that candle burning will deplete O_2 and fasten CO_2 build up in the metal silo.

Baseline grain samples were then collected at trial setup and non-destructive sampling method was carried out thereafter, at 30-days interval for ten months using double tube multi-slotted brass sampling spears. At each sampling interval, an equal sample of 0.5 Kg per replicate was withdrawn. The sampling spear was inserted at different corners of the metal silo and bags to withdraw the samples. Care was also taken to maintain the hermetic conditions of the hermetic technologies by following the procedures described above. Samples were then separated to grain, insects, and dust using 4.7 and 1.0 mm sieves. Various data were recorded including the number and weight of damaged and undamaged grains, live and dead insects, the weight of dust produced and number and weight of rotten (mold) kernels. This study is interested in the percent weight loss data for use in the economic analysis. To estimate the percentage weight loss, collected samples were assessed by the conventional 'Count and weigh' method. Sampled grains were separated into damaged and undamaged, weighed, numbers counted and percentage weight losses for each sample were determined using the formula (Adams and Schulter, 1978):

$$\textbf{Weight loss (\%)} = \frac{(Wu*Nd)-(Wd*Nu)}{Wu*(Nd+Nu)}*100$$

Where, Wu *= Weight of undamaged grain,* Nu *= Number of undamaged grain,* Wd *= Weight of damaged grain, and* Nd *= Number of damaged grain.*

The percentage storage weight loss data was thus collected from the on-station trials and used to perform the economic analysis of hermetic storage technologies versus farmers' storage technologies. In the economic setup, four storage technologies namely the metal silo, super grain bag, actellic treated polypropylene bag and untreated polypropylene bag were also used. Actellic super gold insecticide is one of the two commonly used storage chemicals by smallholder farmers in the country. Percentage weight loss data from naturally infested treatments were used in the analysis to mimic storage conditions at smallholder farm level. Paired t-tests were run in STATA 13 to test the differences between mean percentage weight losses of farmers' storage technologies versus hermetic technologies.

Mean storage losses comparisons between the treated bag and the untreated bag were left out as both are farmers' current storage technologies. Likewise, there was no comparison of the two hermetic technologies since the farmers' practice can only compare their current technologies to either of the hermetic technology options. An incremental approach was used to determine costs of switching from current farmer storage technologies to either a metal silo or super grain hermetic bags. Two common farmer storage technologies of storing shelled grain in polypropylene bags with and without insecticides were controls in this analysis. Bagging is the commonest storage practice in Zimbabwe among smallholder farmers. Interviews with metal silo manufacturers, farm inputs retailers and government officials provided data on input costs, for example price of one tonne metal silo (made using galvanized plain iron sheet), retail price of 50kg super grain bag (Grain pro), 50kg polypropylene bag, candle and rubber band (used for sealing the inlet and outlet openings of metal silo to create an airtight environment), 500g of actellic super gold and monthly maize grain prices between August 2012 and May 2013.

CBA of metal silos and super grain bags for storing one tonne of maize grain over 15 years was done against farmers' current technologies. The life span of the storage investment was taken to be 15 years (Kimenju and de Groote, 2010), therefore the costs and benefits were the sums of the whole life of each storage technology. Super bags are considered to last for two years and have to be replaced thereafter (following perforation by LGB). The costs and benefits were replicated till they had the same useful life with a metal silo to allow for comparison of NPVs (Kassa, 2015). The benefit of storage in this study was taken as the physical weight loss that is abated due to the use of new storage technologies.

7.2.2 Conceptual framework

Most often smallholder farmers are faced with alternative grain storage technologies from which to choose and yet lack relevant information on the costs and benefit of such technologies. Studies that provide information on costs and benefits of new technologies allow farmers to make an informed decision before adoption. In this study, two new stored product methods are evaluated against two farmers' storage practices in Zimbabwe. On station, trial loss data is used. These storage technologies are a metal silo, super grain bag, actellic super dust gold treated polypropylene bag and untreated polypropylene bag. Cost benefit analysis is the analytical framework for this work as guided by ICRA (2010).

7.2.3 Cost benefit analysis

The Cost Benefit Analysis is used for calculating the profitability of an enterprise or a project (ICRA, 2010). According to Gittinger (1982), CBA is a decision tool for determining the net benefit or net income of an enterprise, after computing all costs against benefits, valued in local currency. CBA is widely used as both a financial and economic appraisal tool for various interventions (Bizoza and de Graaff, 2010). This study employs it as a financial tool to measure the profitability of storage technologies in Zimbabwe.

7.2.4 Financial analysis of maize storage technologies

A financial CBA is carried out from the perspective of a person; group or unit directly involved in the project, for example, a smallholder farmer adopting a storage technology. In this case, only expenses made in using the particular storage practice or technology and benefits that will accrue from using of the same are taken into consideration. The Net Present value (NPV), and the Benefit-Cost (B-C) Ratio are the tools of financial CBA, among other tools such as Internal Rate of Return (IRR), that the study will use to determine viability of hermetic storage technologies in Zimbabwe. These have been chosen based on their simplicity and wide appeal (Haruna, 2012). The theoretical framework for NPV and B-C ratios is provided by Gittinger (1982).

7.2.5 Discounting

Discounting is a key element of the CBA framework. Discounting is important as costs and benefits flows do not occur at the same time, and also accrue over a long period of time. Usually, the opportunity cost of capital (OCC) is used as the discount rate (Haruna, 2012). It is defined as the return on the last or marginal investment made that exhausts the last available capital (Haruna, 2012). However, practical application of OCC is problematic as the exact value is unknown. For developing countries, this cost is usually assumed to be between 8% and 15% (Gittinger, 1982). In other instances, discount rates can be based directly on the interest rates payable by farmers on bank loans adjusted for inflation (Atampugre, 2014). The choice of discount rate can make a significant difference to the NPV of a project and consequently to the relative desirability of alternative technologies. In this study, a discount rate of 15% is used, based on the weighted benchmark interest rate as reported by the Reserve Bank of Zimbabwe (Daily News, 29 January 2014). An investment period of 15 years is used for the hermetic storage technologies (Kimenju and de Groote, 2010).

7.2.6 Net Present Value

The Net Present Value of an enterprise is the present worth of the net incremental benefit or incremental cash flow stream which can be economically defined as the difference between total benefits and total costs discounted at the appropriate discount rate. The costs and benefits are computed against a base case or control. Mathematically, according to FAO SAFR, (2002), the *NPV* is expressed as:

$$NPV = \sum (B_t - C_t)/(1+i)^t \quad (1)$$

where B_t is the gross benefits in time t, C_t total costs in time t, t is the time horizon and i is the discount rate. In this study, costs and benefits of storing a tonne of maize grain in metal silos and super grain bags are estimated against farmers' current storage technologies of keeping grain in untreated and treated polypropylene bags. A positive *NPV*, *NPV*>0 means the enterprise generates a net benefit and thus is economically robust. *NPV* is also simple to calculate and is preferred in choosing among mutually exclusive projects as is shown in this study.

7.2.7 Benefit Cost Ratio

Benefit-Cost ratio is obtained when the present worth of the benefit stream is divided by the present worth of the cost stream (Gittinger, 1982). The B/C ratio is given by the following formula:

$$B/C = \frac{\sum_{t=1}^{n} B_t/(1+i)n}{\sum_{t=1}^{n} C_t/(1+i)n} \quad (2)$$

where B_t = benefits in year t, C_t = costs in year t, n = useful life years of technology, i = discount rate

The decision criterion for this ratio is to accept all projects with a ratio equal to or greater than one. In addition to these measures of project worth, a sensitivity analysis is also carried out to assess the capacity of the two new storage technologies to absorb shocks. Sensitivity analysis tests whether the uncertainty over the value of certain variables matters and thus identifies critical assumptions (Australian Government, 2010).

7.2.8 Calculation of additional benefits of storage technologies

CBA of storage loss data was done in Microsoft Excel. A storage period of ten months was used in the analysis to closely represent the storage cycle of smallholder farmers in Zimbabwe (from August to May). Incremental monthly storage loss (physical loss per tonne) data was collected per technology. The expected storage loss abatement from the use of new storage technologies was then calculated using the following formula:

Abated loss (tons) = Monthly Incremental Loss (Farmer technology) –Monthly Incremental Loss (New Technology)

The equation means that the bigger the abated loss, the better the new technology. The benefit of storage was then converted into monetary value by multiplying the monthly abated loss by monthly producer maize price per tonne. The study also considers the salvage values of metal silos and super grain bags as benefits that accrue to the smallholder farmers at the end of 15 years of storage and adds them to the benefit of storage (monetary value of abated loss).

7.2.9 Calculation of additional costs of storage technologies

Costs are calculated as the incremental cost of new storage technologies compared to the control technologies. Costs include both variable and fixed costs. Variable costs are incurred on a yearly basis, from one storage season to another while fixed costs represent the installation costs of acquiring technology and do not vary between seasons. The costs of storing maize in a one-tonne metal silo include the cost of a rubber band, candles and cost of acquiring the one-tonne silo (USD$200). Rubber bands and candles are purchased on a yearly basis. After loading grain into a metal silo, a burning candle is placed into the silo to use up all oxygen to suffocate all pests. The silo is then sealed with adhesive tape or rubber bands.

On the other hand, storing one tonne of grain in super grain bags, include the cost of 20 bags of super bags, and cost of 20 bags of polypropylene bags (act as inside layer of the super bag). It is assumed that super grain bags can only be used for two storage seasons, and then have to be replaced. Therefore acquisition costs of super grain bags technology are recurring every third year of storage. The control technology is bagging with insecticide, where the cost of insecticide is a major component of the storage costs. The study assumes that farmers in Zimbabwe apply insecticides three times a year to stored grain in order to reap maximum storage benefits and this was incorporated into calculations of storage costs.

7.3 Results and discussion

7.3.1 Results of storage losses across storage structures

The grain weight loss in four storage technologies under natural infestation conditions showed differences between farmers' current technologies and hermetic technologies over a period of 10 months (Figure 7.1). Untreated polypropylene bags had the highest percentage grain weight loss (13.23%). Giga et al. (1991) also reported a maize grain weight loss of 13% after eight months of storage in untreated maize in Zimbabwe. Figure 7.1 also shows that the rate of deterioration in grain weight changes over time and across the technologies. Grain weight loss accelerated after four months of storage in treated and untreated polypropylene bags while super grain bags and metal silo maintained a gradual increase. Losses to insects increase at later stages of the storage period and this explains the rapid increase in weight loss in the control storage technologies. Mutambuki and Ngatia (2010) reported similar results. The low percentage weight loss results of hermetic technologies indicated their high level of effectiveness. Table 7.1 shows high statistically significant differences ($p<0.05$) in mean percentage weight loss across the technologies. Super grain bags storage technology recorded the least percentage mean weight loss among the four storage technologies, further revealing the effectiveness of the hermetic technologies compared to polypropylene bags. Section 7.3.2 presents the results of cost benefit analysis of the four storage technologies using on-station trials loss data.

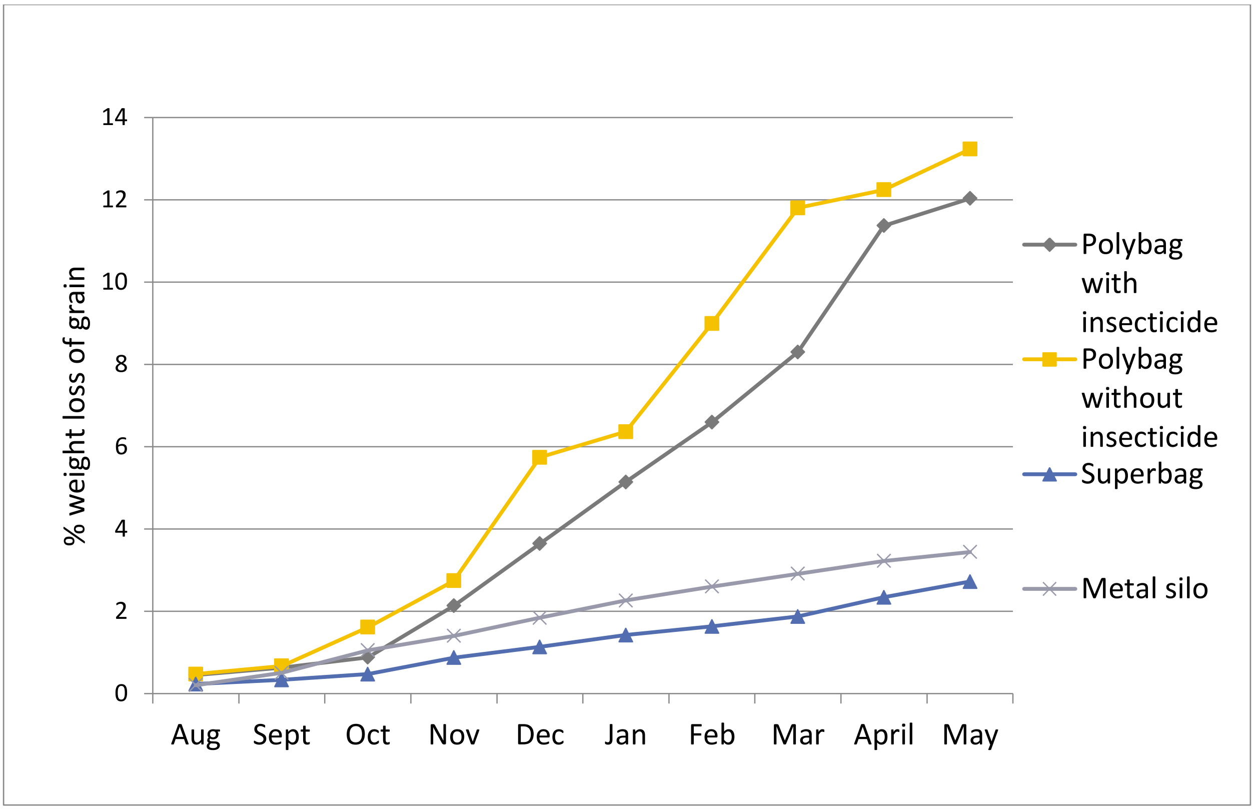

Figure 7.1: Monthly Cumulative Percentage Weight Loss of stored maize grain by storage structure in Zimbabwe

Table 7.1: Mean percentage weight loss of maize grain in four storage practices over ten months of storage

Storage	**Observations**	**Weight Loss (%)**	**Standard Deviation**
Untreated Polypropylene bag	10	6.39[a]	4.96
Treated Polypropylene bag	10	5.12[b]	4.35
Super grain bag	10	1.30[c]	0.85
Metal silo	10	1.94[d]	1.13

*Means followed by the same letter in a column are not significantly different (p<0.05)

7.3.2 Net Present Value and Cost Benefit Analysis

The *NPV* and *B-C* ratios computations for storing a tonne of maize using different technologies are presented in Table 7.2.

Table 7.2: *NPV* and *B-C* ratio of hermetic technologies versus current farmer storage technologies over 15 seasons/years

Storage technology	Untreated bag		Treated bag	
	NPV	*B/C* ratio	*NPV*	*B/C* ratio
Metal silo	$67.21	1.31	$70.26	1.38
Super grain bag	$74.96	1.28	$106.76	1.50

Source: own study. **Assumptions**: Interest rate = 15%, years of storage = 15

Comparing the metal silo and super grain bag against farmer storage technologies, the *NPV*s of both hermetic technologies are positive ($67.21 and $74.96 versus untreated bag; $70.26 and $106.76 versus treated bag, respectively). Both technologies are financially viable at 15% opportunity cost. Super grain bag gives the highest *NPV* (150% that of metal silo) when compared against farmers' storage technology of a treated bag. Likewise the *B-C* ratios of hermetic technologies were greater than that for farmers' storage technologies. The *B-C* ratio of super grain bag against treated bag was revealed to be greater than the *B-C* ratio of metal silo using the same control. Therefore, the super grain bag technology economically performs better than the metal silo. This can be explained by the fact that there are significantly higher costs associated with the purchase of the metal silos. Since the *B-C* ratios are greater than one and *NPVs* are positive, both hermetic storage technologies are economically viable.

Using the two financial performance indicators, overall, hermetic storage technologies are financially viable over farmers' storage technologies. The super grain bag technology recorded the highest *NPV*s. This result also shows that the super grain bag has the highest financial return. Regassa (2014) also found that super grain bags perform better than metal silos using the same parameters of *NPV* and *B-C* ratios. Other studies confirm that the use of metal silos and super grain bags is attractive to farmers (Kimenju and de Groote, 2010). Whereas *B/C* ratios of metal silos in other studies were found to be greater than two (Kimenju and de Groote, 2010; SDC, 2011), in Zimbabwe lower *B-C* ratios of less than two were recorded due to higher cost of the galvanized metal sheet for metal silo fabrication which is imported.

7.3.3 Sensitivity analysis results

A Sensitivity analysis (Table 7.3) was carried out for three storage technologies; metal silo, super grain bag and actellic treated polypropylene bag.

Table 7.3: Sensitivity analysis: *NPV* estimates of hermetic technologies versus the treated bag

***NPV* estimates**	**20 useful years of investment**	**10 useful years of investment**
Metal silo	$83.65	$30.97
Super bag	$119.67	$30.84
Sensitivity Ratios		
Metal silo	0.57	1.68
Super bag	0.36	2.13

Source: Own study. **Assumptions**: Interest rate = 15%, years of storage = 15, residual value of metal silo = $200

Comparing hermetic technologies to actellic treated polypropylene bag is important because hermetic technologies eliminate insecticide use and insecticides are a huge expense being incurred by smallholder farmers, and their application and availability is a major challenge. More so, the investment period of 15 years used for the CBA is a bit conservative since metal silos can have an expected life of 25 to 40 years with proper maintenance (Siebber, 1999; Bern et al., 2013). Thus CBA is repeated using a higher investment period of 20 years. On the other hand, hermetic storage technologies are relatively new in the region and country, and smallholder farmers are not yet skilled in the use, handling and maintenance of the technologies. This may entail higher levels of storage losses in these technologies or even total collapse of the technologies' effectiveness against storage pests. Hermetic technologies work by totally eliminating exchange of gases into and outside the technologies and require no use of insecticides and fumigants. Poor use, handling and maintenance of the technologies can actually reverse the effectiveness of the technologies. Thus it is relevant that the sensitivity analysis captures this possible management issue that may arise among smallholder farmers and reduce the investment period from 15 years to 10 years. A new CBA was computed at 15% discount rate for only one parameter, the *NPV*s of both hermetic technologies against treated polypropylene bagging.

The financial profitability of investing in hermetic storage technologies at smallholder level remains unchanged after the sensitivity analyses. The *NPV* estimates were found to be positive for both hermetic storage technologies under the two sensitivity analysis scenarios. This also shows that hermetic technologies have a clear economic advantage over farmers' current storage technologies, with the super grain bags performing better than metal silos. The reduced investment period for the technologies caused a reduction in the *NPV* estimates of both technologies by more than half. Hermetic technologies are profitable in the long run. High start-up costs of the technologies, particularly buying the metal silo, make it expensive to own the technology in the short run. The study also applied sensitivity ratio (*SR*), to measure elasticity or percentage change in *NPV* as a result of a 1% change in investment lifespan of the hermetic storage technologies versus the treated polypropylene bag. The SRs for both hermetic technologies were found to be greater than 1 under a 10 year's investment period. This means that hermetic technologies are highly responsive to a reduction in expected life. By increasing expected life of the technology to 20 years, the *SRs* were less than 1, showing that *NPV*s are inelastic to changes in the useful life of hermetic technologies, above a benchmark of 15 years. The conclusion from this analysis is that hermetic technologies require huge start-up capital hence a longer investment period is required to recoup the investment capital. The technologies are financially profitable in the long run.

7.4 Conclusion

Storing maize grain using hermetic technologies was found to be most profitable when compared to untreated and Actellic treated polypropylene bags. The B/C ratios were also greater for hermetic technologies. Super grain bags were found to be more profitable than the metal silo. Nevertheless, both technologies were superior to the smallholder farmers' storage technology of treated bags. Therefore, the chapter recommends the use of hermetic technologies as an alternative technology. These eliminate the use of these insecticides yet working effectively against storage pests, including the LGB. It should, however, be also noted that to create and keep gas-tight conditions in silos or bags is a demanding and expensive task that requires pronounced scientific and technical skills. Dissemination of the technology should thus encompass a farmer and artisan training package on proper handling and management of the hermetic technologies to reap maximum benefits from the inert atmospheres created.

Sensitivity analysis results, on the other hand, revealed that both hermetic storage technologies are sensitive to reduction in investment period. This is a result of the high investment costs. This chapter recommends super grain bags for smallholder farmers who are resource limited and cannot invest in a silo since super grain bags have a higher financial return than a metal silo. Metal silos are the most suitable robust storage technology for smallholder farmers who have long term storage investment plans.

This chapter, however, was limited to considering only the abated physical weight loss benefits of hermetic storage technologies. Hermetic storage technologies go beyond reducing physical weight losses of stored grain to maintaining its quality and nutritional value. They work by eliminating the use of insecticides and fumigants that can have negative health and environmental impacts on the lives of smallholder farmers. Therefore, the benefits of storing grain in hermetic technologies go beyond the reduction of physical weight loss of grain. This study sets a benchmark for analysing the financial benefits of storing maize grain using hermetic technologies. These findings suggest that policy makers should consider wide dissemination of hermetic technologies. Provision of credit maybe required to allow farmers to meet the high initial costs.

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CHAPTER 8 CONCLUSIONS, IMPLICATIONS FOR POLICY AND FUTURE RESEARCH DIRECTIONS

8.1 Recap of the purpose of the study

Despite the potential effects of PHL on household incomes, food security and livelihoods, little attention has been given to the economics of PHL and storage technology in studies on household grain management and governments have not adequately addressed the issue of reducing PHL. In Zimbabwe, smallholder farmers still rely on traditional storage practices which cannot guarantee the protection of staple food crops like maize against major storage pests. This is despite the availability of improved storage technologies such as the hermetic metal silos and super grain bags. Interventions in PHL reduction are seen as an important strategy to reduce food insecurity in sub-Saharan Africa (SSA) and to reduce poverty. It is thus imperative to determine the factors that influence storage practices of smallholder farmers in Zimbabwe, in the face of continued PHL in storage. Moreover, the adoption of new improved technology has always been problematic among farmers in developing countries like Zimbabwe. Besides, there are very few countries, from which a country like Zimbabwe can learn from that have assessed the adoption of agricultural storage technologies thus there is a gap of knowledge in this regard. Therefore, it is against this background that this study aimed to provide an in-depth evidence of grain storage management practices of smallholder farmers and their effects on storage losses, maize marketing behaviour and household hunger gap and also evaluated WTP for the new storage technology in Zimbabwe. Evidence on storage losses by storage structure is also scanty in the country and studies that explored potential links between storage technology and household food security and maize marketing behaviour do not exist in the country.

8.2 Conclusions and implications for policy

This study aimed to assess the determinants of grain storage practices and their implications on storage losses, maize marketing behaviour and household food security and also evaluated WTP for the new storage technology by using both on-station trial data and household surveys. The study indicated that significant storage losses are incurred in traditional storage technologies and that hermetic storage technologies are an economically viable and profitable storage technology alternative. The study revealed that both hermetic metal silo and super grain bags storage technologies are sensitive to reduction in investment period. This is a result of the high investment costs that are associated with the technologies. The results, however, indicated that super grain bags are more suitable for smallholder farmers who are resource limited and cannot invest in a silo since super grain bags have a higher financial return than a metal silo. On the other hand, metal silos are the most suitable and economically robust storage technology for smallholder farmers who have long-term storage investment plans. This implies that credit may be required to boost the adoption of hermetic technologies among smallholder farmers.

In terms of WTP for a metal silo, the study results indicated that storage loss, non-food crop quantity, equipment value, vegetable income, informal activity participation and household head characteristics of age and marital status were the key determinants of willingness to pay for a one-tonne metal silo storage technology in Zimbabwe. The amount of grain lost in storage had a positive influence on farmers' WTP for a metal silo. This result implies that current storage practices are not effective against storage losses and the metal silo can be an alternative effective storage technology to curb storage losses and hence improve their food security and livelihoods. The results indicated that income variables except business and wage income had a positive influence on WTP for a metal silo. This implies that increasing a household's income will help ease the financial constraints that often impede technology investments among smallholder farmers. In addition, the results revealed that married respondents and young farmers are more ready to pay for metal silos than unmarried respondents and old farmers.

The study results revealed that total grain stored, the value of non-food crops, business and wage income, access to extension services and household head's age, education years and marital status, significantly influenced the choice of storage technologies among smallholder farmers. The total grain stored influenced smallholder farmers to use the insecticide storage technology versus the no-insecticide technology. This implies that the total amount of grain for storage will influence smallholder farmers to use improved storage technology. The results indicated that households with a higher value of non-food crops showed higher chances of using the insecticide storage technology relative to the no-insecticide technology while, on the other hand, households with income from business and wage activities showed less likelihood to use the insecticide storage technology. This suggests that households with access to business and wage income have fewer chances of storing grain hence are unlikely to choose the insecticide storage technology. Older households had higher chances of using the insecticide storage technology indicating that farming experience influences the choice of grain storage technologies. Marital status also increased the chance of using the insecticide storage technology suggesting that married household heads are less risk-averse. The results of the study further indicated that better-educated smallholder farmers had higher chances of using the insecticide storage technology. This implies that improving knowledge of farmers on post-harvest management will influence them to use improved storage technology. Although access to extension had a negative influence on the choice of storage technology, it is important that government develops specific extension trainings on storage technology particularly, the use of insecticide storage so as to equip farmers with proper storage skills and information.

The study results also revealed that storage practices had significant effects on both maize marketing behaviour and hunger gap of smallholder farmers. The use of insecticide storage increased the chances of farmers to become net sellers of maize. Using insecticide storage reduces the amount of grain that is lost in storage hence farmers are able to preserve the amount of grain available for consumption and also for sale. This implies that safe storage of maize promotes smallholder farmers' net maize selling behaviour. Household head's gender, marital status, quantity harvested, market location, farming systems and district location were other factors that influenced maize marketing decisions of smallholder farmers in Zimbabwe. The results indicated that male farmers were more likely to participate in the market as net maize sellers than their counterparts. This implies that male farmers are more market-oriented than their counterparts who may be more concerned about meeting household consumption needs. Males also dominate in decision making in households. Results showed that married farmers were more likely to participate in the market as net buyers of maize than their counterparts. Married farmers have bigger families than unmarried farmers hence their production may not be adequate to meet household consumption needs thus they end up buying more than what they sell on the market. Furthermore, the study results indicated that availability of local markets increased the chances of farmers to become net sellers of maize. This implies that transaction costs affect market participation behaviour of smallholder farmers.

Moreover, results showed that the majority of the households experienced hunger gap with an average intensity of 4.7 months. This means that food insecurity is an issue of concern among smallholder farmers. Although the results of the study revealed that farmers who used no treatment on stored grain had better chances of not incurring hunger gap in the study areas, this may imply that these households had less demand for storage and had access to other sources of livelihoods like business and wage income hence had other means of securing the food needs for the family. Household characteristics such as age, household size, gender, marital status, education years, location, and being an A1 model or old resettlement farmer also significantly influenced the occurrence of hunger gap. Household size positively influenced the occurrence of hunger gap implying that a larger household size increased the chances of experiencing hunger gap.

On the other hand, land size negatively influenced the occurrence of hunger gap. This suggests that farmers who had larger sizes of cultivated land showed lower chances of experiencing hunger gap than their counterparts. Households with more years of schooling had lower chances of incurring hunger gap. This could be that more educated households are the ones who have other spurces of income like business and wage activities and thus have less demand for stored grain. They just buy from market processed maize meal. Results revealed that farmers in Shamva district showed higher chances of experiencing a hunger gap than those in Makoni district, while farmers in the A1 model and old resettlement schemes had better chances of incurring zero hunger gap. Farmers in the A1 and old resettlement schemes have better access to land and other productive resources hence the lower chances of incurring hunger gap. District location-specific characteristics should be investigated to explain the differences in hunger gap occurrence between the two districts of study.

On the other hand, hunger gap intensity increased if no-insecticide storage technology was used to store maize grain. This implies that farmers lacked proper grain post-harvest management skills and knowledge and thus took no precautionary measures to safeguard their grain from storage pests. The results revealed that the quantity of grain harvested, total grain stored, income from business and wages and land size had a negative effect on hunger gap intensity while hunger gap intensity increased if household head was married. Larger quantities of stored grain and the quantity of maize harvested reduced hunger gap intensity and this suggests that improving the capacity of farmers to store maize grain as well as boosting their maize production will help to reduce hunger gap intensity. The negative influence of business and wages income on hunger gap intensity implies that promotion of activities that increase farmers' access to income may reduce the hunger gap intensity. The results also revealed that marital status increased hunger gap intensity and this suggests that married households have more food security burdens than their counterparts.

8.3 Policy recommendations

To address the issue of reducing PHL and the continued use of traditional storage technologies among smallholder farmers, this study recommends a holistic approach that addresses production, storage and marketing issues of smallholder farmers in the maize value chain. This means that policy-makers should aim to find strategies of reducing PHL and increasing the adoption and dissemination of improved storage technology while creating a conducive environment to improve the attractiveness, viability and success of smallholder maize production. To achieve this, the study specifically recommends the following:

a. *Promote the dissemination of hermetic metal silo and super grain bags storage technologies in the smallholder farming areas*

Safe storage of grain is important to meet constant demand against a variable supply and this requires effective storage technology. Results of this study showed that storing maize grain using hermetic technologies was found to be most profitable when compared to farmers' current use untreated and Actellic treated polypropylene bags. Hermetic storage technologies eliminate the use of these insecticides yet working effectively against storage pests, including the LGB. It should, however, also be noted that to create and keep gas-tight conditions in silos or bags is a demanding and expensive task that requires scientific and technical skills. Dissemination of the technology should thus encompass farmer and artisan training on proper handling and management of the hermetic technologies to reap maximum benefits from the inert atmospheres created. It should, however, be noted that the provision of credit may be required to allow farmers to meet the high initial costs of the metal silo technology.

b. *Improving smallholder post-harvest management and skills*

The study recommends policy priority towards building an effective post-harvest management system for smallholder farmers which will reduce household hunger gap and promote maize market participation behaviour thereby allowing farmers to reap benefits from incomes realized through maize sales. Such a development will improve smallholder farmers' livelihoods in general. In particular, the results of the study show the need for policy priority towards organizing extension training for smallholder farmers on grain post-harvest management including the use of new hermetic storage technologies. Farmers should be taught on the proper use of grain protection methods in order to reduce storage losses. Policy priority towards providing adult learning programs to increase smallholder farmers' education is also recommended. Policy priority towards the creation of farmer marketing groups is also recommended. The study results indicate that local markets promote net maize selling behaviour of smallholder farmers hence policies that reduce transaction costs are highly recommended.

c. Provide support for the production of maize and other non-food crops

The study recommends policy priority towards increasing the production of maize and other non-food crops among smallholder farmers so as to reduce hunger gap occurrence and promote the adoption of improved storage technologies. Policies that improve farmers' access to cultivatable land and other productive resources are recommended in order to boost agricultural production of smallholder farmers and hence the adoption of improved storage technologies.

d. Employment creation

Income is an important variable in technology adoption. The results of the study indicate that vegetable income and participation in informal activities increased smallholder farmers' WTP for a metal silo technology. Hence policies that create employment in the smallholder farming areas are recommended. This may include but not limited to creation of viable local agricultural vegetable markets.

e. Targeting younger and married household heads

Government should target younger household heads for dissemination of improved storage technologies as they are more likely to invest in the metal silo storage technology. Government should also target the married households for sustainable dissemination of new storage technologies as married household heads are less risk averse. However, care should be taken not to side-line older and unmarried household heads.

8.4 Study limitations and suggested areas of further research

While this study has set a benchmark for analysing the economic benefits of storing maize grain using hermetic technologies, the study was limited in considering only the abated physical weight loss benefits of hermetic storage technologies. Hermetic storage technologies go beyond reducing physical weight losses of stored grain to maintaining its quality and nutritional value. They work by eliminating the use of insecticides and fumigants that can have negative health and environmental impacts on the lives of smallholder farmers. Therefore, the benefits of storing grain in hermetic technologies go beyond the reduction of physical weight loss of grain and thus it is suggested that future research be conducted taking into considering these added benefits. The study also used storage loss data collected from on-station trials and hence a research on the economic viability of hermetic technologies should be conducted using on-farm storage loss data. The other limitation of the study is the dependence on cross-sectional data. The use of panel data would have provided more robust impact estimates. The study has also not investigated the effect of storage practices on market participation in terms of how much maize was sold or bought from the market. The effect of storage technologies on volumes of maize purchased or sold in the market should be explored in further research. Lastly, the data used in the study was from two districts only, suggesting that a more nationally representative study be conducted to provide further evidence.

APPENDICES

APPENDIX A: Questionnaire

INTRODUCTION

My name is ________________________ from the University of KwaZulu Natal. The University is conducting a research that is looking at **determinants of storage practices, and implications on storage losses, grain marketing behaviour and food security of smallholder farmers in Zimbabwe**. There are no right and wrong answers to the questions. The information will be treated as **CONFIDENTIAL** and is solely for academic purposes only. Your participation in this research study is completely voluntary. The interview will take about 60 minutes.

HOUSEHOLD IDENTIFICATION PARTICULARS

1.	Province Name	PROV	
2.	DistrictName	DIST	
3.	Ward Number		
4.	Enumeration Area Name	EA	
5.	GEOCODE		
6.	Village/Locality Name	VILL	
7.	Household Serial Number	HH	
8.	Category	CATEGORY 1 = A; 2 = B; 3 = C	
9.	GPS Coordinates	South S_DD	dec. degrees .
		East E_DD	dec. degrees .
10.	Names of Household Head		
11.	Names of Main Respondent (if different from Household Head)		
12.	*(Enumerator: after the demography table is complete, record the member number of the respondent.)*	RESPMEM	
13.	Cell phone number of the main respondent	CELLPHONE	

14. RESPONSE STATUS ***1=Complete2=Refusal 3=Moved out of SEA4=Non-contact5=Household dissolved due to death 6 = Household dissolved due to other reasons eg., divorce***	

15. ASSIGNMENT RECORD									
							Day/	Mon/	Year
A	Name of Enumerator		ENCODE			Date completed			
B	Name of Supervisor		SPCODE			Date checked			
C	Name of DE Operator		DECODE			Date Entered			

MODULE 1: HOUSEHOLD DEMOGRAPHIC CHARACTERISTICS

Reference Period: Last twelve months KEY VARIABLES: HD1

HH member ID	Name of household member (start with household head, then spouse, adult children, relatives, non-relatives and the remaining children)	What is …'s relation to HH head? ***See code sheet***	What is ……sex? ***1= Male 2=Female***	In which year was …… born? ***Record the year e.g., 1970***				***<u>Ask if MEM was born 2003 or earlier.</u>*** What is… marital status?	***<u>Ask if MEM was born 2008 or earlier.</u>*** What is the highest level of education …………. completed?	How many months did …..live away from the household in the last 12 months? ***Record the months***	**<u>ADULTS(Born 2000 or earlier)</u>** Was ...involved in salaried or other wage activities in last 12 months? ***1 = Yes ; 2 = No***	Was. ..involved in formal or informal business activities in the last 12 months? ***1 = Yes ; 2 = No***
	HD1	**HD2**	**HD3**	**HD4**				**HD5**	**HD6**	**HD7**	**HD8**	**HD9**
01												
02												
03												
04												
05												
06												
07												
08												

09												
10												
11												

HD2		**HD5**	**HD6**		
1 = head *2 = spouse* *3 = Son/Daughter* *4 = parent* *5 = brother/sister* *6 = nephew/niece*	*7 = son/daughter-in-law* *8 = brother/sister-in-law* *9 = parent-in-law* *10 = grandchild* *11 = other relative* *12 = Unrelated*	*1= Married monogamous* *2= Married polygamous* *3 = Separated* *4 = Divorced* *5 = Widow/widower* *6 = Never married* *7 = Other, specify…*	*00=None* *01=Sub A/B; Grade 1* *02=Standard 1; Grade 2* *03=Standard 2; Grade 3* *04=Standard 3; Grade 4* *05=Standard 4; Grade 5*	*06=Standard 5; Grade 6* *07=Standard 6; Grade 7* *08=Form 1; Grade 8* *09=Form 2; Grade 9* *10=Form 3; Grade 10* *11= Form 4; Grade 11* *12=Form 5; Grade 12*	*13=Form 6 Lower* *14= College Student* *15= University Undergrad Student* *16= Tertiary Certificate; Diploma* *17= Bachelor's Degree* *18 = Master's Degree and Above.*

MODULE 2A: LIVESTOCK ASSETS

Reference Period: NOW and Last 12 Months **KEY VARIABLE: ANTYPE**

	Animal type	Number of animals on holding NOW	How many animals of each type are owned by …..?					How many in total where sold live or as meat over the last 12 months?
			Male Spouse	Female Spouse	Other males	Other Females	Jointly owned	
	ANTYPE	**ANNUM**	**ANMAL**	**ANFEM**	**ANOM**	**ANOF**	**ANJNT**	**ANSOLD**
1	Cows							
2	Oxen							
3	Bulls							
4	Heifers							
5	Steers							
6	Calves							
	TOTAL							
7	Goats							
8	Sheep							
9	Pigs							
10	Donkeys							
11	Chicken							
12	Guinea fowls							

13	Ducks and geese							
14	Turkeys							
15	Pigeons							
16	Bee hives							
17	Rabbits							
18	Fish ponds stocked							

MODULE 2B: ANIMAL PRODUCTS

Reference Period: Last 12 Months   KEY VARIABLE: PRODUCT

	Product	How much was produced?				How much was sold on average per month?		
		For how many months were you producing	How often did you produce?	On each occasion, how much did you produce?		How often did you sell?	On each occasion, how much did you sell?	
				Quantity	Units		Quantity	Units
	PRODUCT	**PMONTH**	**PFREQ**	**PQUANT**	**PUNITS**	**SFREQ**	**SQUANT**	**SUNITS**
1	Cow milk							
2	Goat milk							
3	Eggs (from pullets only)							
4	Broilers							
5	Fresh fish							

PFREQ/SFREQ

1 = daily
2 = every other day
3 = once per wk
4 = none
5 = other specify

PUNITS/SUNITS

1=90kg bag
2=50kg bag
3=20lt tin
4=tons
5=5lt gallon
6=kilogram
7= liter
8 = Other

MODULE 2C: EQUIPMENT, IMPLEMENTS AND GADGETS

Reference Period: NOW KEY VARIABLE: ASSET

Asset			How many......are in working condition? (***Enter 0 if none)***	Asset			How many......are in working condition? (***Enter 0 if none)***
		ASSET	***HOWMANY***			***ASSET***	***HOWMANY***
Farm implements	*1*	Tractor		Transport	16	Lorry	
	2	Disc plough			17	Car/pick up	
	3	Ox-plough			18	Motorbike	
	4	Ox - Cultivator			19	Ox cart	
	5	Ox - Ridger			20	Donkey cart	
	6	Ox - Planter			21	Push cart (Chingoro)	
	7	Ox - Harrow			22	Bicycle	
	8	Water pump			23	Wheelbarrow	
	9	Generator		Communication	24	Radio	
	10	Sheller			25	Mobile phone	
	11	Knapsack sprayer			26	TV	
					27	Satellite Dish	
Household Implements	12	Solar panel					
	13	Hammer mill					
	14	Gas cooker		Other	28	Blair Toilet	
	15	Electric stove			29	Pit Latrine	
					30	Flash toilet	

MODULE 3A: LAND OWNERSHIP, ACCESS AND USE

Reference Period: Last Main Cropping Season 2012/13 KEY VARIABLE: TYPE1; TYPE2; PARCEL

Type of Parcel			How many parcels?	**PARCEL 1**			**PARCEL 2**			**PARCEL 3**			**PARCEL 4**		
				Area	Units	Owner	Area	Units	Owner	Area	Units	Owner	Area	Units	Owner
TYPE 1	**TYPE 2**		**PNUM**	**PSZ1**	**PUN 1**	**PON1**	**PSZ2**	**PUN 2**	**PON2**	**PSZ3**	**PUN 3**	**PON3**	**PSZ4**	**PUN 4**	**POWN4**
1. Cultivated parcels															
	Own	***11***													
	Rented-in	***12***													
	Borrowed in	***13***													
	Other(Specify	***14***													
2.Other parcels															
	Rented out	***21***													
	Borrowed out	***22***													
	Garden	***23***													
	Fallow	***24***													
	Wetland	***25***													
	Orchard	***26***													
	Uncleared Arable	***27***													

Owner		Area Units
1 = Male Spouse	5 = Joint	1 = Hectare
2=Female Spouse	6 = Other	2 = Acres
3 = Other males		3 = Square meters
4= Other females		

MODULE 3B: CROPPING ANDHARVEST

Reference Period: Main 2012/13 Agricultural Season KEY VARIABLES: PID; PNUMB; PCROP

Parcel ID			How many plots are in this parcel?	Plot number	What is the area of this plot?		What main crop did you plant in this plot or what land use was practiced?	How much crop did you harvest from this plot?	
					Area	Units		***Quantity***	***Units***
PID			**NUMP**	**PNUMB**	**PAREA**	**PUNIT**	**PCROP**	**HQUANT**	**HUNITS**

PCROP

1 = Maize	*6 = Groundnuts*	*11 = Mixed beans*	*16 = Other*
2= Sorghum	*7 = Soybean*	*12 = Roundnuts*	
3 = Rice	*8 = Seed Cotton*	*13 = Cowpea*	
4 = Millet	*9= Virginia Tobacco*	*14 = coffee*	
5=Sunflower	*10= Burley Tobacco*	*15 = Sweet potato*	

PUNITS

1=90kg bag	*6=kilogram*
2=50kg bag	*7=other*
3=20lt tin	
4=tons	
5=5lt gallon	

HUNITS

1 = Hectare

2 = Acres

3 = m^2

MODULE 3C: CROP SALES

Reference Period: Main 2012/13 Agricultural Season

Enumerator: <u>Ask for all crops other than maize, tobacco and cotton   KEY VARIABLES: CROPNAME</u>

CROP HARVESTED		**How much of each crop you harvested did you sell?** **Enumerator: Sales include barter or exchange for goods and services**	
		QUANTITY	**UNITS**
CROPNAME	**CROPCODE**	**SCROP**	**SUNITS**

CROPS

1 = Maize *6 = Groundnuts* *11 = Mixed beans* *16 = Other*

2 = Sorghum *7 = Soybean* *12 = Roundnuts*

3 = Rice *8 = Seed Cotton* *13 = Cowpea*

4 = Millet *9=Virginia Tobacco* *14 = coffee*

5 = Sunflower *10= Burley Tobacco* *15= Sweet potato*

UNITS

1=90kg bag *6=kilogram*

2=50kg bag *7= liter*

3=20lt tin *8 = Other*

4=tons

5=5lt gallon

MODULE 3D: MAIZE PLOT MANAGEMENT

Reference Period: Main 2012/13 Agricultural Season KEY VARIABLES: PPID;

PLOT ID	Who was the primary decision maker on this plot?	What main variety was planted on this plot?	How much seed was planted on this plot?		How did you acquire most of the input?	How many KGs of basal dressing did you apply?	How did you acquire most of the input?	How many KGs of top dressing did you apply?	How did you acquire most of the input?	What main pest problem was observed in the field during plant growth?		What main disease problem was observed during plant growth?
			Quantity	***Units***						***Within 4wks after emergence***	***From 4 wks onwards***	
PPID	**MGR**	**MVAR**	**PSEED**	**UNIT**	**SSEED**	**QBDR**	**SBDR**	**STDR**	**QTDR**	**PESTE**	**PESTL**	**DSEAS**

Manager **Method of procurement** **UNITS** **Early Pests** **Mid/Late Pests** **Field Diseases**

1 = Male 1 = Cash Purchase 7 = Own retained 1=90kg 7= liter 1 = Stalk borer 1 = Stalk 1 =Maize Streak Virus

Spouse	(100%)	seed	bag			borers	
2 = Female Spouse	2 = Govt. Subsidy	8 = Other Subsidy	2=50kg bag	8=Other	2 = Worms	2 = Locusts	2 = Grey Leaf Spot
3 = Other males	3 = Credit	9 = Other	3=20lt tin		3 = Leaf hoppers	3 = Leaf aphids	3 = Northern Corn Blight
4 = Other females	4 = Exchange		4=tons		4 = Chaffers	4 = Termites	4 = Rust
5 = Joint	5 = Transfer		5 = 5lt gallon		5 = Others	5 = Ear Maggots	5 = White Spot
6 =Other	6 = Donation/Gift		6 = kg		6=None	6 = Other	6 = Other
						7=None	7=None

MODULE 3E: VEGETABLE PRODUCTION

We would like to know the value of all the vegetables the household produced whether they were sold or not. Because the volume units for vegetables are not all standard, the focus will be on the value of production not the quantity produced. Summarize the average value for each type of vegetable produced each time during the last twelve months.

3.1	Did this household produce any vegetables from the beginning of November 2012 to the end of October 2013 *1 = Yes; 2 = No*→***Skip to Module 4***	

Reference Period: Last twelve months. KEY VARIABLE: VEGNAME

Which **vegetables** did the household **produce/harvest** from the beginning of November 2012 to the end of October 2013?*(**Enumerator**: Write name of vegetable in full)*	Enter vegetable code	How many times did the household harvest …. between November 2012 to the end of October 2013?	What was the AVERAGE value of harvest in USD each time the household harvested?
VEGNAME	**VEGCODE**	**VEGX**	**VVALUE**

VEGCODE

1 = Cabbage *6 = Eggplant* *11 = Chinese cabbage*

2 = Rape	*7 = Chomolia*	*12 = Butternut*
3 = Tomatoes	*8 = Carrots*	*13 = Tsunga*
4 = Onion	*9 = Green beans*	*14 = Spring onions*
5 = Okra	*10 = Green Maize*	*15 = Other vegetables*

MODULE 4: PRE-STORAGE HANDLING OF MAIZE

Reference Period: Last Main Cropping Season 2012/13 KEY VARIABLES: PREACT; PREPRACT

Activity		Please indicate whether you followed these practices		**Ask only if practice was performed.** When performing this operation, how many males and how many females participated?	
	PREACT	**PREPRACT**	**PRACT**	**MALES**	**FEMALES**
1	Stooking	i) Placing stalks with cobs on standing heaps in the field *1 = Yes; 2 = No*			
2	De-husking and sorting	*i)* Removing husks from cobs early so drying can commence immediately, fast and within shortest possible time *1 = Yes; 2 = No*			
		ii) Sorting small damaged/unfit cobs from full clean cobs *1 = Yes; 2 = No*			
3	Transportation and drying	i) Moving cobs from field early to a more secure location for further drying *1 = Yes; 2 = No*			
		Ask if response to 2(i) is No, otherwise go to 3(iii)			

		ii) Placing cobs (in husks) in crib for further drying*1 = Yes; 2 = No*			
		<u>Ask if response to 2(i) is Yes, otherwise go to 4(i)</u> iii) Placing cobs (de-husked)in crib for further and faster drying*1 = Yes; 2 = No*			
		iv) Placing cobs on other platforms (floor, broad rock, roof) for further drying *1 = Yes; 2 = No*			
4	Shelling	i) Grading maize stocks *1 = Yes; 2 = No*			
		ii) Machine shelling *1 = Yes; 2 = No*			
		iii) Hand shelling*1 = Yes; 2 = No*			
		iv) Beating with sticks *1 = Yes; 2 = No*			
		v) Disposing grain shelling debris well away from store *1 = Yes; 2 = No*			
5	Cleaning	i) Winnowing/removing debris and rotten kernels *1 = Yes; 2 = No*			
		ii) Cleaning inside store to remove last season grain remains *1 = Yes; 2 = No*			
6	Placing bags away from floor	i) Placing bags on wooden pallet or raised platform not directly on floor *1 = Yes; 2 = No 3.=N/A*			

Grain Handling Structure		How many are controlled by HH?	**UNIT1**					**UNIT 2**					**UNIT 3**				
			What is the capacity?		Year of Make	Who owns the structure?	Who controls use of structure?	What is the capacity?		Year of Make	Who owns the structure?	Who controls use of structure?	What is the capacity?		Year of Make	Who owns the structure?	Who controls use of structure?
			Qty	Units				Qty	Units				Qty	Units			
	STRUCT	**STRNU**	**SQ1**	**SU1**	**SG1**	**SOWN1**	**SCONT1**	**SQ2**	**SU2**	**SG2**	**SOWN2**	**SCONT2**	**SQ3**	**SU3**	**SG3**	**SOWN3**	**SCONT3**
1	Drying Crib on stilts																
2	Traditional granary (pole &mud plastered)																
4	Ordinary Brick Granary																
5	Improved Brick granary																
6	Metal Silo																
7	Other (specify)																

Who owns		**Who controls**		**UNITS**	
1 = Male Spouse	*5 = Joint*	*1 = Male Spouse*	*5 = Joint*	*1=90kg bag*	*6=kilogram*
2 = Female Spouse	*6 = Other*	*2 = Female Spouse*	*6 = Other*	*2=50kg bag*	*7= Liter*
3 = Other males		*3 = Other males*		*3=20lt tin*	*8 = Other*
4 = Other females		*4 = Other females*		*4=tons*	
				5=5lt gallon	

MODULE 5: Investments and Ownership of Grain Handling Structures

Reference Period: Last Marketing Season 2012/13 KEY VARIABLES: STRUCT; UNIT1

MODULE 6: MAIZE STORAGE PATTERNS AND LOSS ASSESSMENT

Reference Period: Last Marketing Season 2012/13 KEY VARIABLES: VESSEL; VNUM

Storage Facility		In which month did use of facility begin?	What form was the grain in at the time of storage?	What amount of stock was put in vessel?		What amount of weight loss was incurred during storage?		What was the major cause of storage loss?	What main loss control measure was applied?	Did quality deteriorate during storage? *1 = Yes; 2 = No*	Which month was last grain removed from facility?
				Qty	Units	Qty	Units				
VESSEL	**VNUM**	**VMONTH**	**VFORM**	**VQT**	**VUNT**	**VQLS**	**VLUN**	**VLCAUSE**	**VCONT**	**VQUAL**	**VMTHEND**
Traditional granary (pole &mud plastered)	Unit 1										**Month and year**
	Unit 2										

	Unit 3										
Woven Basket (Cylindrical Shape with Flat bottom)	Unit 1										
	Unit 2										
Improved brick granary	Unit 1										
	Unit 2										
Metal Silo											
Poly grain bags											
Hermetic bags											
Room in House											
Other (specify)											

VMONTH		**Form of grain (VFORM)**	**Cause of loss (VLCAUSE)**		**Loss control measure (VCONT)**		
1 = Jan	*7 = July*	*1 = Shelled*	*1 = Rodents*	*7 = Theft*	*1 = Insecticide treatment*	*7 = milled grain to flour*	*13 = trap& kill*
2 = Feb	*8 = Aug*	*2 = Unshelled without husks*	*2 = Weevils*	*8 = Rain*	*2 = Biological treatment (ash etc)*	*8 = semi milled grain*	*14 = elevated platforms*
3 = March	*9 = Sept*	*3 = Unshelled with husks*	*3 =Large Grain Borer*	*9 =Other*	*3 = Smoking*	*9 = shelled and bagged*	*15 = applied sand*
4 = April	*10 = Oct*	*4 = Other*	*4 = Termites*		*4 = Fumigant tablets*	*10 = gave grain away*	*16 = covered with plastic*

5 = May	*11= Nov*	*5 = Rotting/Decay*	*5 = Other Crop/veg pesticides*	*11 = planted local maize*	*17 = Other*
6 = June	*12 = Dec*	*6 = Fire*	*6 = Cow dung*	*12 = store local maize*	*18=None*

MODULE 7A: SUFFICIENCY OF OWN MAIZE HARVEST FOR HOUSEHOLD CONSUMPTION

Reference Period: Current Marketing Season 2013/14 KEY VARIABLES: STMGR; STID

Store Manager	**Who are the primary maize store managers NOW?**	**Duration of Maize Self-Sufficiency**		**Response Code**
STMGR	**STID**	**MZSUFF**		**RCODE**
1		*1.1*	Does Store Manager 1 still have in stock maize grain/flour from 2012/2013 harvest? *1 = Yes→**Skip to Q**1.3* *2 = No→**Skip to Q 1.2***	
		1.2	In which month did the store manager run out of maize from his/her own 2012/13 harvest? *See code sheet*	Month and year
		1.3	Under normal consumption and use, in which month will this store manager expect to run out of maize from his/her own 2012/13 harvest? *See code sheet*	
2		2.1	Does Store Manager 2 still have in stock maize grain/flour from 2012/2013 harvest? *1 = Yes→**Skip to Q 2.3*** *2 = No→**Skip to Q 2.2***	

		2.2	In which month did the store manager run out of maize from his/her own 2012/13 harvest? *See code sheet*	
		2.3	Under normal consumption and use, in which month will this store manager expect to run out of maize from his/her own 2012/13 harvest? *See code sheet*	
3		*3.1*	Does Store Manager 3still have in stock maize grain/flour from 2012/2013 harvest? *1 = Yes→**Skip to Q 3.3*** *2 = No→**Skip to Q 3.2***	
		3.2	In which month did the store manager run out of maize from his/her own 2012/13 harvest? *See code sheet*	
		3.3	Under normal consumption and use, in which month will this store manager expect to run out of maize from his/her own 2012/13 harvest? *See code sheet*	

Household Maize Consumption Rate

7.1	How many days does a 50KG bag of maize grain last under normal maize meal consumption by your household?	**DAYS**		

MODULE 7B: HOUSEHOLDMAIZE SELLING BEHAVIOR

Reference Period: Last Marketing Season 2012/13

7.1.1	Did the household sell or exchange the maize crop for goods and services *1 = Yes; 2 = No→**Skip to Module 7C***	

KEY VARIABLE: STYPE; MEMBER ID; QUARTER

Sale type	Who primarily decided whether or not	Transaction decisions	QUARTER1 May – July 2012	QUARTER2 Aug – Oct 2012	QUARTER3 Nov – Jan 2013	QUARTER4 Feb – April 2013

	to sell or exchange the crop?										
STYPE	**MEMID**	**TRANS**		**QTR1**		**QTR2**		**QTR3**		**QTR4**	
1. Cash Sales		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units____
		2	Market Location								
		3	Main Buyer								
		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____
		2	Market Location								
		3	Main Buyer								
2. Exchange for goods and services		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____
		2	Market Location								
		3	Main Buyer								
		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____
		2	Market Location								
		3	Main Buyer								

7.1.2	For the largest sale transaction conducted, did you receive a price based on the quality or grade of the grain	*1 = Yes; 2 = No* →***Skip to***	

	Module 7C	
7.1.3	If the price received was based on quality, in what grade or quality class was the maize? *1 = Grade A; 2 = Grade B; 3 = Grade C; 4 = Grade D; 5 = Other*	

Main Buyer			**Market Location**				
1 = Small trader	*3 = GMB*	*5 = Coop*	*1= Local village*	*5 = Other Ward in District*	*4 = Rusape*	*7 = Bindura*	*9 = At Homestead*
2 = Private Company	*4 = Other Farmers*	*6 = Other*	*2 = Other Village in Ward*	*3 = Shamva town*	*6 = Mutare*	*8 = Harare*	*10 = Other (Specify)*

MODULE 7C: HOUSEHOLD MAIZE PURCHASING BEHAVIOR

Reference Period: Last Marketing Season 2012/13

7.2.1	Did the household purchase (cash or exchange) any grain or flour for home consumption*1 = Yes; 2 = No*→***Skip to Module 8A***	

KEY VARIABLE: PTYPE; MEMBER ID; QUARTER

Purchase type	**Who primarily decided whether or not to purchase maize crop?**	**Transaction decisions**	**QUARTER1 May – July 2012**	**QUARTER2 Aug – Oct 2012**	**QUARTER3 Nov – Jan 2013**	**QUARTER4 Feb – April 2013**
PTYPE	**MEMID**	**PTRANS**	**QTR1**	**QTR2**	**QTR3**	**QTR4**

1. Purchase of grain		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____
		2	Market Location								
		3	Main Seller								
2. Purchase of maize meal		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____
		2	Market Location								
		3	Main Seller								
3. Other Purchase of maize		1	Total Volume	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____	Qty______	Units_____
		2	Market Location								
		3	Main Seller								

Enumerator: Ask the following questions if household purchased maize grain

7.2.2	For your largest purchase transaction carried out, was the price paid based on the quality or grade of the grain *1 = Yes; 2 = No* **→*Skip to Module 8A***	
7.2.3	If the price paid was based on quality, in what grade or quality class was the maize? *1 = Grade A; 2 = Grade B; 3 = Grade C; 4 = Grade D; 5 = Other*	

Main Buyer **Market Location**

1 = Small trader 3 = GMB 5 = Coop 1= Local village 5 = Other Ward in District 4 = Rusape 7 = Bindura 9 = At Homestead

2 = Private 4 = Other 6 = 2 = Other Village in 3 = Shamva town 6 = 8 = Harare 10 = Other

Company	*Farmers*	*Other*	*Ward*	*Mutare*	*(Specify)*

MODULE 8: INSECTICIDE USE (AWARENESS, INFORMANTS AND PRECAUTIONARY BEHAVIOR

Reference Period: 2012/13 Marketing Season

Insecticide procurement and use (INSECTICIDE)					
1	Did you use any insecticide/chemical treatment on stored grain in 2012/13 marketing season? *1 = Yes*→***Skip to Q4****; 2 = No*				
2	Have you conceded or accepted the current levels of physical loss of grain in storage as part of life? *1 = Yes; 2 = No*				
3	How do you compensate for the losses that occur in storage each year? *1 = purchase grain; 2 = receive relief from institutions; 3 = get help from relatives; 4 = plant more area; 5 = increase yields; 6 = none* ***Enumerator: Go to Module 8B after this question***				
4	What main type of insecticide product was purchased? *1= Actellic Gold; 2 = Hurudza; 3 = Attack Plus; 4 = Ngwena yeDura; 5 = Delta AG; 6 = Chikwapuro; 7 = Shumba Supermax; 8 = Super Guard; 9 = Other(specify)*				
5	How many containers/bottles of insecticide did you purchase?	**Unit size** *1 = 250g; 2 = 500g 3=200g*		**Number of units**	
6	Were you able to purchase your preferred product? *1 = Yes; 2 = No*				
7	From whom did you buy the insecticide? *1 = General Dealer; 2 = Input Stockist; 3 = Supermarket; 4 = Hardware Shop; 5 = Trader; 6 = Other*				

8	From where did you purchase insecticide? *1= Local village; 2 = Another Village in Ward; 3 = Shamva town; 4 = Rusape; 5 = Another Ward in District; 6 = Mutare; 7 = Bindura; 8 = Harare 9 = Other(specify)*	
9	Who paid for the insecticide?*1= Male Spouse; 2 = Female Spouse; 3 = Other male member; 4 = Other female member; 5 = Other*	
10	Who managed the treatment application?*1= Male Spouse; 2 = Female Spouse; 3 = Other male member; 4 = Other female member; 5 = Other*	
11	For how many months was the insecticide effective against insect pests such as weevils and LGB? **Enumerator: *Record the months***	
Treatment of grain with insecticide (TREAT). *Enumerator: Focus on the type of insecticide used*		
1	One (250g) container of the insecticide was applied to how many bags when treating grain? **Enumerator: If farmer is familiar with use of a 500g container, ask the number of bags that can be treated and divide by 2. *Record the number of bags***	
2	How many times did you apply insecticide treatment on the same batch of grain? Enumerator: *Record the number of times*	
3	How many days must elapse between treatment and utilization of treated grain? Enumerator: *Record the number of days*	
4	How did you dispose of insecticide containers? *1 = reused; 2 = dumped in latrine; 3 = threw away in backyard; 4 = other*	
5	What main precautionary measure did you take when applying treatment? *1= wearing protective equipment;2 = reading labels and instruction; 3 = following instructions and prescribed dosage; 4 = other*	
6	Has any member of household experienced any ailment or health problems caused by the insecticide? *1 = Yes; 2 = No*	

7	What could happen in this community if most maize stores are damaged by insects? *1 = local prices will rise; 2 = Poor health; 3 = maize shortages; 4 = hunger will set it; 5 = would need relief food; 6 = Need to look for grain elsewhere; 7 = Other*		
Training and information sources (TRAINING)		**Male Spouse**	**Female Spouse**
1	Have you had training or received information on appropriate instructions for use and handling of insecticide? *1 = Yes; 2 = No→**Skip to Q3***		
2	Who provided the most important training or information? *1= a fellow farmer; 2 = extension officer; 3 = retailer; 4 = Other*		
3	***Ask if respondent has not received any training.*** Which person can provide such training or information? *1= a fellow farmer; 2 = extension officer; 3 = retailer; 4 = Other*		
4	If you needed advise on insecticide use, who do you approach? *1= a fellow farmer; 2 = extension officer; 3 = retailer; 4 = other*		
5	What other sources of advice are available to influence your practice within the village network? *1= a fellow farmer; 2 = extension officer; 3 = retailer; 4 = Other 5=None*		
Hazards and safety of insecticide use (HAZARD)		**Male Spouse**	**Female Spouse**
1	Do you think normal insecticide use has any ability to harm or produce hostile effects to human health? *1 = Yes; 2 = No→**Skip to Module 8B***		
2	What main danger can normal insecticide use cause? *1 = small effect;2 = medium effect;3 = large effect; 4 = fatal effect*		

MODULE 9: METAL SILO USER ASSESSMENT

Reference Period: Last Main Cropping Season 2012/13

1	Is there grain in the Metal Silo currently? *1 = Yes; 2 = No*→***Skip to subsection on Training on use and handling Metal Silo***	
2	Was the maize treated with insecticide before loading? *1 = Yes; 2 = No*	
3	How many 50kg bags of own harvested grain were loaded during the initial loading? ***Enumerator: record the number of 50kg bags***	
4	Was the maize loaded into silo all harvested from the same season? *1 = Yes; 2 = No*	
5	Is the silo placed in a weather proof (cool, well ventilated and dry) location *1 = Yes; 2 = No*	

	Manager's Experience with Silo		**Male Spouse**	**Female Spouse**
1	What is the primary use of maize kept in the metal silo? *1 = own consumption; 2 = market; 3 = for exchange with goods; 4 = for exchange with services; 5 = seed*			
2	What is the most important change you have experienced since you started using of the metal silo? *1= reduction in storage losses; 2 = better hygiene; 3 = better health outcomes; 4 = more grain available for family consumption; 5 = easier to sell stored grain; 6 = less PH handling work; 7 = other*			
3	In what manner does it matter whether one eats from the silo or from the standard poly bag?*1 = no damaged kernels or foreign matter;* *2 = meal smells different; 3 = meal tastes different ; 4 = less exposure to chemicals; 5 = no change; 6 = Other*			
4	Based on your current experience, how acceptable do you rate metal silos? *1= Preferred; 2 = Acceptable; 3 = Conditionally acceptable;*	(i) Control of pests and rodents		
		(ii) Cost of acquisition		
		(iii) Ease of loading and off lading		
		(iv) Placing of the silo in the house		

	4 = Unacceptable	(v) Security of grain against theft		
5	Based on your experience, what is your recommendation on metal silos to non-users? *1= Recommend without reservation; 2 = Recommend with further evaluation; 3= Recommend with limited application; 4 = Insufficient information to recommend; 5 = Not recommended*			
6	How could the metal silo be improved to make it more satisfying for your use? *1 = Bigger Opening; 2 = Painting outside; 3 = None; 4 = Other*			
7	What problems do you face now with use of metal silos? *1 = None; 2 = Loading is cumbersome; 3 = Off-loading is cumbersome; 4 = Other*			
Training on use and handling Metal Silos				
1	Have you received training on use and handling of metal silos? *1 = Yes; 2 = No*→***Skip to Q3***			
2	Who conducted the training? *1= a fellow farmer; 2 = extension officer; 3 = Artisan 4 = Other*			
3	Does this 1 ton metal silo meet your maize grain storage needs? *1 = Yes; 2 = No*			
4	Do you plan to purchase additional silos *1 = Yes; 2 = No; 3 = do not know*			

MODULE 10: NON-METAL SILO USERS

Reference Period: Last Main Cropping Season 2012/13

		Male Spouse	Female Spouse

1	Are you aware of hermetic metal silos being used by other farmers in your area? *1 = Yes; 2 = No→**Skip to Module 11***		
2	If a 1 ton metal silo which lasts until 2033 costs $200 when delivered at your home, could you afford it? *1 = Yes; 2 = No→**Skip to Q7***		
3	***If YES to Question 2***, Are you willing to purchase one such silo? *1 = Yes; 2 = No→**Skip to Q7***		
4	Who in the household will approve the placement of an order? SKIP QUESTION 5 & 6 AFTER THIS QUESTION *1= Male Spouse; 2 = Female Spouse; 3 = Other male member; 4 = Other female member; 5 = Other 6=Joint*		
5	***If NO to Question 3,*** what stops you from purchasing a metal silo at that price? *1 = Suppliers are unknown; 2 = No savings; 3 = Not sure; 4 = Other*		
6	What can be done to reduce or eliminate this hindrance? *1 = Train more artisans; 2 = Provide Loans; 3 = Allow exchange with crops; 4 = Other*		
7	Who in the household stands to benefit most if storage losses are reduced? *1= Male Spouse; 2 = Female Spouse; 3 = Other male member; 4 = Other female member; 5 = Joint; 6 = Other*		
8	Who in the household stands to lose most if a metal silo is purchased? *1= Male Spouse; 2 = Female Spouse; 3 = Other male member; 4 = Other female member; 5 = Other*		

MODULE 11: AGENDA FOR AUTHORITIES ADMINISTERING MAIZE INDUSTRY

We would like your views on how the national administration of the maize industry can be improved. We want to know how changes in procurement and pricing arrangements of maize can incentivize farmers to adopt improved storage technologies.

11.1	Is it viable for you to grow commercial maize as a business under the current grain marketing conditions?*1 = Yes; 2 = No*	

11.2	Explain:	
11.3	What is the most important issue for farmers that government must address to improve viability of commercial maize production?	

MODULE 12: OFF-FARM INCOME AND REMITTANCES

12.1 We would like to talk about all **ADULTS (12 years and above)** household members who have earned income from **SALARIED EMPLOYMENT OR INFORMAL WAGE LABOUR ACTIVITIES OR PENSIONS** between **November 2012 to October 2013**. These activities include all formal salaried employment and all casual labour for which members were paid cash or an in-kind wage, including agricultural and non-agricultural labour. Include also the value of any pensions received from **November 2012 to October 2013**. Do not include income from business activities, which will be captured on the next page. ***Instruction: Please list the Member IDs (MEM) and names of all persons 12 years and above from the demography Table column HD8 = YES above.***

Reference Period: **November 2012 to October 2013**

Person ID and name	What are the 3 most important **salaried employment or informal wage labour activities or pensions** that …. was involved in at any time from **November 2012 to October 2013** ***See code below***	**How many months did ….**carry out most of this activity?	From **November 2012 to October 2013**, how much **cash** did the person **receive** for each month that he or she worked? If the person earned **in-kind wages**, e.g. food or other goods, what is the **approximate total cash value per month?**

MEM	NAME	WACTNAME	WACTCO	W01	W02

Salaried Employment / Informal Wage Activities (WACT)

1=On a smallholder farm	*5=Other industrial work*	*9=Shop attendant*	*13=Worker lodges or camps*
2=On a commercial farm	*6=Teacher*	*10=Non-agricultural piece work*	*14=Worker photo safari*
3=In a factory	*7= Other Civil servant*	*11=Pension/NSSA*	*15=Worker safari/game hunting*
4=In a mine	*8=Clerk in private business*	*12=Private company*	*16=Worker craft/curio production*
			17=Other (specify) __________

12.2 We would like to talk about all household members who participated in **FORMAL OR INFORMAL BUSINESS ACTIVITIES** from **November 2012 to October 2013**.This should include any income generating activity other than the selling of your own farm produce or sale of your own labour for wages.

Instruction: Please list the Member IDs (MEM) and names of all members 12 years and above from the demographic Table column HD9 = YES above

Reference Period: **November 2012 to October 2013**

Person ID and name		Please list at most 3 most important **business activities**that this person was involved in at any time from **November 2012 to October 2013**. *(See codes below)*		**How many months did ....**carry out most of this business activity?	**On average, what were the monthly revenues and expenses?**	
					Average **Gross** Monthly Revenue (USD)	Average Monthly Expenses (USD)
ME	**NAME**	**BACTNAME**	**BACTCODE**	**BACTM**	**BACTR**	**BACTE**

BACT 1

1=crop trading	*9=butchery(all meats including game, cooked or uncooked)*	*17=blacksmithing/tinsmithing*	*25=curio business*
2=livestock trading	*10=agric. services (e.g., plowing, planting, spraying)*	*18=traditional healing*	*26=hair saloon / barbershop business*
3=retailer/shop owner	*11=milling*	*19=fishing and selling*	*27=other (specify)* ______________
4=marketer/hawker/vendor	*12=cooking oil processing& selling*	*20=precious stone mining (small scale)*	
5=firewood/charcoal production & selling	*13=agro-processing*	*21=gathering ants & caterpillars & selling*	
6=carpentry	*14=tailoring*	*22=collecting mushroom /fruits& selling*	
7= builder / construction	*15=bicycle repairing*	*23=collecting wild honey & selling*	
8=local brewing & selling	*16=weaving (cloth and reed/basketry) and selling*	*24=beekeeping & honey selling*	

12.3. Cash Remittances: We would like to know the TOTAL CASH that was **received or sent/given** between **November 2012 and October 2013.**

12.3.1	**CASH RECEIPTS:** Between **November 2012 and October 2013,** did any **member of this household** **receive** cash from any **non-household** member or organization? ***1=Yes 2=No2 ->SKIP to 11.3.2***	**HH01**	

Reference Period: Between **November 2012 to October 2013**

ID	**Name** of non-**household member/organization who sent or gave** cash to this household ***List the names of non-household members who have sent cash to this household***	**Relation to head** ***(See codes below)***	Total amount of cash in USD **received by this household** from a non-household member or organization between ***November 2012 and October 2013***
RMEM	Name	**RM01**	**RM02**
1			
2			
3			
4			
5			
6			

12.3.2	**CASH SENT/GIVEN OUT**: Between **November 2012 and October 2013**, did any **member of this household send/give** cash to any **non-household** member or organization? ***1=Yes 2=No*** *->End Interview*	**HH02**	

Reference Period: Between **November 2012 to October 2013**

ID	**Name** of non-**household member or organization who received cash from this household** ***List the names of non-household members who received cash from this household***	**Relation to head** ***(See codes below)***	Total amount of cash in USD **sent/given by this household** to a non-household member or organization between **November 2012 to October 2013**
SMEM	Name	**SM01**	**SM02**
1			
2			
3			
4			
5			

6				

Relation to Head

1 = head	*5 = brother/sister*	*9 = parent-in-law*
2 = spouse	*6 = nephew/niece*	*10 = grandchild*
3 = Son/Daughter	*7 = son/daughter-in-law*	*11 = other relative*
4 = parent	*8 = brother/sister-in-law*	*12 = Unrelated*

THE END

Thank you for your cooperation

APPENDIX B: Variance Inflation Factor results of MNL model of storage choice

Variable	**Collinearity statistics**	
	VIF	Tolerance
Ttstored	1.23	0.812917
PCEquip_value	1.99	0.502479
mar_status	1.90	0.525983
Sex	1.88	0.532664
PCbusiwages_income	1.75	0.571263
PCLivestock_value	1.64	0.609215
PCLandsize	1.10	0.907077
PCVegetable_income	1.35	0.742873
PCValuNONFOOD_Crop	1.15	0.867333
extension_acc	1.03	0.967077
own_cell	1.11	0.902441
Age	1.57	0.637918
Educyears	1.59	0.630371
Mean VIF	1.48	

Source: Own study, MNL VIF Output.

APPENDIX C: Contingency Coefficients results, MNL model of storage choice

	extension_acc	own_cell	mar_status	Sex
extension_acc	1.0000			
own_cell	0.0836	1.0000		
mar_status	0.0240	0.1327	1.0000	
Sex	0.0743	0.0944	0.6424	1.0000

Source: Own study, MNL Contingency Coefficients output.

APPENDIX D: Variance Inflation Factor, Logit model of WTP

Variable	Collinearity statistics	
	VIF	Tolerance
Nonfoodcrop_quantity	1.24	0.803495
Age	1.39	0.719271
EQUIPValue	1.46	0.683477
Educyears	1.33	0.753632
Landsize	1.28	0.780699
Value_livestock	1.70	0.589645
ValueANIM_PRODsales	1.13	0.886826
Vegincome	1.11	0.901851
Hhsize	1.05	0.954997
perc_loss	1.07	0.933114
Mean VIF	1.28	

Source: Own study, Logit VIF output

APPENDIX E: Contingency Coefficients results, Logit model of WTP

Variable	marital_status	informalactivity	salariedactivity	gender
marital_status	1.0000			
informalactivity	0.0767	1.0000		
salariedactivity	-0.0629	-0.0501	1.0000	
Gender	0.6366	0.1415	0.0280	1.000

Source: Own study, Contingency Coefficients output

APPENDIX F: Variance Inflation Factor, Ordered probit model

Variable	**Collinearity statistics**	
	VIF	Tolerance
insecticide storage	1.62	0.617259
Age	1.54	0.647739
Educyears	1.64	0.609376
location (Shamva)	1.79	0.559531
Gender	1.85	0.541082
mar_status	1.97	0.508012
market location	1.10	0.905451
extension_acc	1.14	0.876805
hh_size	1.15	0.871237
QMZE_harvested	1.14	0.874826
Percloss	1.21	0.826509
own_cell	1.13	0.888731
A1	3.15	0.316989
Communal	3.99	0.250871
Old resettlement	3.99	0.287215
Other storage	1,47	0.677979
land size	1.18	0.844966
Mean VIF	1.80	

Source: Own study, VIF Ordered probit output.

APPENDIX G: Contingency Coefficients of Ordered probit model

Variable	Gender	Mar_status	Own_cell	Extension_acc	A1	Communal	OR	Insecticide_treatment	Other storage	Shamva
Gender	1.0000									
Mar_status	0.6421	1.0000								
Own_cell	0.0979	0.1356	1.0000							
Extension_acc	0.0696	0.0208	0.0867	1.0000						
Marketlocation	0.0133	0.0221	0.0052	0.1698	1.0000					
A1	0.1069	0.0324	0.0828	-0.0427	0.0456	1.0000				
Communal	-0.0339	0.0143	0.0131	-0.1335	-0.0983	-0.3517	1.0000			
OR	0.0211	0.0667	-0.1064	0.1249	0.0882	-0.3013	-0.6115	1.0000		
Insecticide_treatment	0.1493	0.1706	0.0606	-0.0902	0.0263	0.0476	0.0539	-0.0722	1.0000	
Other storage	0.0082	-0.0345	0.0672	-0.0383	0.0572	0.1650	-0.0579	-0.0661	-0.4687	1.0000
Shamva	0.1428	0.1375	0.0216	-0.2068	-0.0938	0.4644	0.1717	-0.3514	0.1652	0.1075

Source: Own study, Contingency Coefficients ordered probit

APPENDIX H: Variance Inflation Factor, Logit model of hunger gap

Variable	**VIF**	**Tolerance**
hh_size	1.02	0.981791
Age	1.39	0.717521
Educyears	1.49	0.671066
Perc_loss	1.03	0.972710
Landsize	1.21	0.824597
Busiwagesinc	1.25	0.801585
Ttstored	1.51	0.664174
QMZE_harvested	1.34	0.744106
Mean VIF	1.28	

Source: Own study, VIF logit hunger gap output

APPENDIX I: Contingency Coefficients results, Logit model of hunger gap

	farming_system	gender	mar_status	own_cell	extension_access	dist	storage_practices
farming_system	1.000						
Gender	-0.1145	1.000					
mar_status	-0.1026	0.6367	1.000				
own_cell	-0.0648	0.0890	0.1265	1.000			
extension_access	0.1426	0.0732	0.0209	0.0875	1.000		
Dist	-0.5867	0.1569	0.1524	0.0303	-0.2100	1.000	
storage_practices	0.0027	-0.1041	-0.1326	-0.0027	0.0394	-0.0580	1.000

Source: Own study, Contingency coefficients logit hunger gap output