ECONOMICS OF GRAIN STORAGE TECHNIQUES FOR SMALLHOLDER FARMERS IN KILOSA DISTRICT, TANZANIA

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ABSTRACT

Smallholder farmers lack knowledge on the amount of income lost from improper grain management after harvest thus they make uninformed decisions on the storage technique to use. This study aimed at assessing the economics of grain storage techniques in Kilosa district in Tanzania. Specifically, the study aimed at performing a cost benefit analysis of grain storage techniques, to determine farmers' perceptions on the effectiveness of grain storage techniques and to establish determinants of farmers' choices of grain storage techniques in the study area. A random sample of 153 farmers was drawn from farmers in Changarawe and Ilakala villages. The Net Present Value (NPV) and Cost Benefit Ratio (CBR) results from a cost benefit analysis of grain storage techniques suggest that it is more profitable to invest in the modern hermetic techniques known as Purdue Improved Crop Storage Bags (PICS) and metal silos than investing in traditional granaries and polypropylene bags. Likert scale and principal component analysis were used to deduce farmers' perceptions on effectiveness of techniques. Farmers perceived hermetic modern techniques as the most effective in reduction of post-harvest crop losses. The Multinomial logistic regression was used to establish determinants of farmers' choices of storage techniques where age was positive and significant for the choice of traditional granary over metal silo at 10% ($P<0.1$), expected price after storage was significant and negative for traditional granary and polypropylene bags over metal silo at 5% ($P<0.05$) and 10% ($P<0.1$) respectively. Education level of household head, investment costs, number of crops cultivated and percentage of crop stored for sell were significant and positive for the choice of polypropylene bags and PICS over metal silo at 1% ($P<0.01$) and 10%($P<0.1$) respectively. The study concluded that hermetic techniques are not only feasible investments but also more effective in reduction of grain loss. The study recommends that farmers should invest in the feasible techniques while been financially supported to purchase effective grain loss reduction storage techniques for food security.

DECLARATION

I, RITHA EMMANUEL LUOGA, do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

_________________________ _________________________

Ritha Emmanuel Luoga Date

(MSc. Candidate)

The declaration above is confirmed by;

_________________________ _________________________

Dr. Khamaldin Mutabazi Date

(Supervisor)

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DEDICATION

This thesis is dedicated to my beloved parents Prof Emmanuel Luoga and Mrs. Veneranda Luoga and my siblings, Cecilia, Gabriel, Neema and Immaculate Luoga, whom together have supported me throughout my entire academic life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

ASDS	Agricultural Sector Development Strategy
BCR	Benefit Cost Ratio
CPB	Cereal and other Produce Board
FAO	Food and Agriculture Organization of the United Nations
HS	Hermetic Storage
IITA,	International Institute of Tropical Agriculture
IRR	Internal Rate of Return
LGB	Large Grain Borer
MOA	Ministry of Agriculture
NGO	Non-Governmental Organization
NPV	Net Present Value
PCA	Principal Component Analysis
PHC	Population and Housing Census
PHDR	Poverty and Human Development Report
PHL	Postharvest Loses
PICS	Purdue Improved Crop Storage
REPOA	Research for Poverty Alleviation
SDC	Swiss Agency for Development and Cooperation
SUA	Sokoine University of Agriculture
URT	United Republic of Tanzania
USAID	United States Agency of International Development
USD	United States Dollar
VICOBA	Village Community Banks

B	Beta
e	Error term

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

In many parts of Africa, certain crops are produced throughout the year. However, major food crops such as grains (cereals and legumes) are normally seasonal crops. Grains contribute to the bulk of the world's calories and protein (Tharanathan, 2003). Consequently, the food grains produced in one harvest period, which sometimes may last for only a certain period must be stored for consumption and future household income needs until the next harvest. One of the setbacks to grain storage and hence agricultural growth is yield losses due to pests during storage, whereby food grains are severely destroyed by insects and other pests (Dubey *et al*., 2008). Therefore, the principal aim of any storage system must be to maintain the crop in its best condition for as long as possible. Storage methods should minimize losses, but must also be appropriate in relation to other factors such as economies of scale, labor and building costs (FAO, 2015).

In the past, traditional grain storage structures such as sisal bags, plastic containers and traditional granaries such as "*vihenge*" were mostly used in Tanzania where food grain was dried, and stored in such structures, then shelled for further storage (Golob, 1988; Ndengwa, 2016). This was effective but with recent climatic changes farmers are forced to store their grain before being properly dried and in the presence of storage pests, farmers experience high losses (Golob *et al*., 2002; Kadjo *et al*., 2013). Empirical literature show that traditional storage systems are associated with high household pests infestation, theft, shorter storage periods and grain exposure to physical damage due to temperature changes. However, improved storage techniques that have been developed and introduced in Tanzania reduce storage losses. Mdangi *et al.* (2013) suggests that the use of improved storage structures reduces rodent infestation which could lead to major savings especially in the amount and quality of stored food available to households. These include hermetic storage techniques such as metal silos, plastic silos and high-density polypropylene bags which reduce gas exchange, lowers pest infestation and reduce damage through temperature changes (Tefera *et al.,* 2011a).

Like in any other developing countries, Tanzanian farmers are faced with challenges not only in production but also in management of grain after harvest. Lack of appropriate grain storage techniques has led to 20-30% grain losses, particularly due to postharvest pests (Tefera, 2012; Kalita and Kumar, 2017). As a result, smallholder farmers move from being sellers to buyers of grains few months after harvest. Farmers fail to realize the potential impact of food storage on poverty reduction and greater food security as they are unable to store their produce and sell surplus production later at attractive prices (Tafera, 2012).

Storage creates value to both producers and consumers but to be able to capture that value, human inventiveness must be used to maintain grain quality during storage. Despite the realization of importance of storage, its potentiality is undermined by the incidence of increasingly destructive storage pests (Hugo *et al.*, 2010). Insect pests affecting stored maize like weevils and large grain borers (LGB) are the most common in East and South Africa and cause serious damage to grain after it has been harvested. According to William *et al*. (2016), farmers experience 20%-50% loss after 3-6 months of storage and sometimes total loss under worst scenario as a result of destructive pests during storage. Stored grains are also damaged by rodents such as rats and temperature changes which may cause dampness.

In Tanzania, rural storage has long been practiced at peasant level. The nature of storage facilities is not complicated, mostly traditional and improved traditional facilities. According to FAO (2015), rates of adoption of new storage techniques at farm level have often been disappointing. Certain costs are incurred by farmers in grain storage so as to ensure food supply until the next harvest or in expectation of price increase during a high demand season if grain is stored for sale. Grain storage costs include fixed and variable costs of storage facilities. The fixed costs of owning facilities are incurred annually regardless of whether facilities are used and these are depreciation costs, capital costs and insurance. Variable costs of grain storage facilities include costs of handling, insect control, monitoring and storage losses.

Grain storage involves substantial costs and risks incurred by farmers in storage as well as potential benefits for farmers. Storage benefits include social benefits such as food supply over the entire season till next harvest and financial benefits from income earned from selling grain after storage. According to Muthami (2017), performance of the on farm storage can be evaluated through the study of costs and benefits involved.

Imminent techniques for grain storage have sometimes been promoted without being subjected to trials and economic analysis (Kimenju, 2010). The newly developed storage techniques identify best practices and innovative arrangements for improving income and nutrition of farm households. For this reason, improving storage systems is a priority for farmers and policy-makers as poor storage facilities contribute the most to post harvest losses (Rugumamu *et al.,* 2011). The knowledge on costs and benefits accrued to new techniques and improved post-harvest management are required by the farmers to reduce crop losses and maximize their returns. This study determined benefits and costs accrued to farmers from alternative grain storage techniques. The study also analyzed farmers' perceptions on the effectiveness of traditional and modern storage techniques used in the region in reducing storage crop loss. Furthermore, the study analyzed the determinants of farmers' choices of storage techniques.

1.2 Problem Statement and Justification

Successful farm storage enables farmers to store grains when prices are attractive for rural farmers in developing countries. However, with the existing indigenous storage techniques, the market is subject to considerable short term and inter-seasonal grain price fluctuations, where farmers are forced to sell their produce cheaply at harvest due to projected losses on storage but later buy food at higher prices (Midega, 2016). Such fluctuations affect the interests of both producers and consumers (Oladejo, 2016). According to FAO (2012), in Tanzania, low investment in storage techniques lead to post harvest losses accounting for USD 19.9 and USD 10.8 per tonne per annum for small and large holder farmers, respectively.

Although storage losses continue to constrain grain supply, storage techniques are overlooked in grain management studies in developing countries (Ndunguru *et al.*, 2014). Some previous studies in Tanzania describe the type of storage facilities used by farmers in various areas but do not provide information on cost implications and benefits accrued to these storage techniques. Shabani *et al.* (2015) conducted a research on maize storage and consumption practices of farmers at Handeni District, Tanzania and how they affect mycotoxin contamination of maize flour. The study did not cover aspects on costs and benefits implied by investing in maize storage techniques. However, a study by Mbwambo *et al.* (2016) on the economic evaluation of improved grain storage in Babati district in Tanzania performed an economic analysis but focused on a single hermetic storage, specifically on Purdue Improved Crop Storage (PICS) bags. Other studies include

(Likhayo *et al*., 2016; Yakubu *et al*., 2011; De Groote *et al*., 2013; Murdock *et al*., 2012; Baoua *et al*., 2013; Moussa *et al*., 2014; Chigoverah and Mvumi, 2016; Midega *et al*., 2016). The studies focused only on economics of hermetic storage techniques but not traditional storage techniques thus lacking comparisons among the techniques. This study focused on the economics of both, hermetic and traditional storage techniques for comparisons.

Another study by Ashimogo (1988) conducted in Kilosa district, Tanzania on the economics of on-farm maize storage techniques employed a cost benefit analysis to perform an economic analysis on two traditional structures and a village communal warehouse. Over time, there have been technological improvements on the storage systems such as hermetic storage techniques introduced in the country. However, their economics is not yet known. This study undertook a cost benefit analysis of traditional polypropylene bags, granaries, modern air tight bags, and metal silos used by farmers in Kilosa district, Tanzania in recent time.

Furthermore, the study by Ashimogo (1988) was based on statistical procedure only. To further provide a deeper methodological insight that will better inform policy, this study combined both statistical and econometric procedures to determine factors influencing farmer’s choice of a particular storage structure. Despite a wide distribution of hermetic grain storage techniques across Tanzania, none of storage studies have attempted to profile farmers’ perception on hermetic techniques as compared to traditional grain storage techniques. This study aims at contributing to this identified gap by determining farmers’ perceptions of grain storage techniques in reduction of crop loss. Basing on the theory, Ashimogo (1988) employed a competitive storage theory with an assumption that the demand and supply of storage techniques is determined by price of grain during peak and scarcity periods. This study was based on the rational choice theory where farmers are assumed to be rational and will choose a storage technique that reduces storage loss.

1.3 Objectives and Hypotheses

1.3.1 General objective

The general objective of the study was to assess the economics of grain storage techniques for small holder farmers in Kilosa district in Tanzania so that storage techniques that increase farmers' household income and reduce risks of postharvest losses can be promoted.

1.3.2 Specific objectives

i. To analyze the costs and benefits of grain storage techniques.
ii. To analyze farmers' perception on the effectiveness of grain storage techniques.
iii. To identify the determinants of choice of grain storage techniques.

1.3.3 Research hypotheses

i. H_O: There is no significant difference in farmers' perception on the effectiveness of storage techniques.
ii. H_O: Factors such as age, gender, education, household size, farm size, number of crops cultivated, investment costs, storage benefit, farmers' perception and expected price after storage have no influence on farmers' choice of grain storage techniques.

1.4 Research Question

What are the costs and benefits associated with the use of grain storage techniques.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Key Terms

2.1.1 Concept of cost benefit analysis on investment projects

An investment project can be defined as the decision to make some current expenses in the hope of future benefits. Whenever a project implies the act of allocating economic resources such as capital, knowledge and infrastructure hoping to attain future benefits is an investment project. In order to determine the viability of a project such as investment in different technology options, methodology of economic and financial analysis as outlined by Gittinger (1982) is adopted. Financial and economic analyses estimate the net-benefits of a project investment based on the difference between the with-project and the without-project situations. They have similar features. However, the financial analyses of the project compare benefits and costs to the enterprise, while the economic analyses compare the benefits and costs to the whole economy.

Since investment in a project will involve a future stream of costs and benefits, these must be discounted to find their present worth. The net present value (NPV) and the benefit-cost ratio (BCR) are used in this analysis. The NPV represents the present worth of the income stream generated by an investment (in this case the storage technique to the farmer). The BCR represents the present worth of the benefit stream divided by the present worth of the cost stream. A sensitivity analysis is taken to determine how favorable the technique is when some factors change.

2.1.2 Smallholder farmers

According to FAO (2010), a farmer is a well identified decision-maker, most of the time head of a family presenting a certain degree of "steadiness". The farm is well defined by a set of clearly identified plots, which either belong to the farmer (who, in this case, possesses the corresponding titles) or are hired from a landlord, who can produce proof of his or her rights. A statistical definition of smallholder farmers is very difficult. This accounts for the scarcity of statistical data on performance of smallholders. According to FAO (2015), smallholder farmers can be defined as those marginal and sub-marginal farm households that own or/and cultivate less than 2.0 hectare of land. Smallholder farmers constitute mainly the rural poor, because of the notion that smallholders refers to poverty, although poverty is essentially relative but the concept excludes rural poor who are not able to operate a farm on their own.

2.1.3 Description of grain storage techniques

2.1.3.1 Traditional storage techniques

These are indigenous techniques for grain storage that have been constructed from locally available materials which exist in the farmers' location. They are a product of decades, maybe centuries based on experience of users and their ancestors and are well adopted to both, types of grain for which they are intended, and the environment they are employed. According to FAO (2009), traditional storage techniques are grouped into temporary stores such as storage of grain on the roof and storage on the ground and long term grain storage such as storage cribs made exclusively from plant materials and vihenge made from cow dung, mud and timber, materials which are readily available to farmers. For this study, polypropylene bags used with or without insecticides were also regarded as traditional storage techniques.

2.1.3.2 Modern storage techniques

To maintain good grain quality and reduction of food losses, storage systems must be improved. According to Novarro (2012), the most common improved grain storage systems are hermetic storage techniques, aeration storage systems and refrigeration of grains. Hermetic storage technique (HS), also known as "*sealed storage*" or "*sacrificial sealed storage*" is an ancient method to control insect infestation and preserve the quality of grain (Quezada *et al*., 2006).

The hermetic storage functions through reducing oxygen (O_2) and increasing carbon dioxide (Sanon *et al.,* 2011). This is achieved by the aerobic respiration of grain, insects, and molds which create a modified atmosphere within the storage container (Quezada *et al*., 2006). According to Njoroge *et al.* (2014), lack of oxygen causes insects to suffocate and eventually die of asphyxiation. The main advantages of hermetic storage techniques are simple to use, feasible, eliminate the need of toxic chemical (insecticides) or fumigations, climate control and environmentally friendly (Navarro, 2012). Hermetic storage is a technology that enables farmers to store their grains with negligible loss of quality and quantity (Suleiman, 2015).

The most common examples of hermetic storage techniques used in Sub Saharan Africa are Perdue Improved Crops Storage (PICS) bags also known as triple-layer bags consisting of three nylon liners. This technology was created in late 1980's under the USAID project for the preservation of cowpea grain in sub-Saharan Africa (Murdock *et al*., 2003). Another hermetic technique include the grain-pro super bag which is a portable bag that consists of a single reusable layer of 0.078 mm thick plastic film made from 2 plains polyethylene films between which is sandwiched a plastic layer that act as a gas and moisture barrier (Baoua *et al*., 2013; Suleiman, 2015). A metal silo is another airtight storage technique which is a cylindrical, square or rectangular prism structure, constructed from a high quality galvanized iron sheet and hermetically sealed with a top inlet and a smaller bottom lateral outlet (Bokusheva *et al*., 2012). Metal silos are available in different capacities of 250 kg, 500 kg, 1000 kg, 1200 kg, and 1500 kg. The main advantage of metal silo is hermetically sealed and provides protection for both short and long time storage against insect pests, pathogen, birds, molds, rodent, theft, and other domestic animals (Gitonga *et al.*, 2015). Other hermetic structures include plastic drums, hermetic cocoons, plastic and metal tins.

2.2 Grain Storage in Tanzania

The storage of grain in Tanzania is done at both, national and at producer level. According to REPOA (2015), until 1970s, Tanzania had no policy on storage for agricultural products. However, following the occurrence of the Large Grain Borer (LGB) in the 1980s which resulted in high Post Harvest Loses (PHL) of cereals that led to endangered food security in the country, the government began to support farmers to reduce PHL. Achieving food security in the country is primarily the government's priority. To achieve this, the government has been formulating and implementing relevant strategies and programs under the Agricultural Sector Development Strategy (ASDS). The ASDS provides a policy and a strategic system for inclusive agricultural growth and reduced rural poverty through investment by both private and public sectors in different stages of agricultural produce value chain namely at storage, processing, appropriate packaging, transportation and marketing. This is estimated to reduce significantly post-harvest loses.

At national level, the government ensures inter-annual grain supply stabilization through supporting grain storage and marketing activities by constructing storage facilities such as warehouses in the villages. At the producer level, smallholder farmers practice seasonal grain storage to ensure food supply throughout the year and income after selling surplus grain. In order to appreciate the advantages of farmers' grain management strategies, considerations of pre storage and storage practices is necessary. The major pre storage factors and practices that influence grain quality and that might cause losses if carried out improperly are the harvesting time, transport process from field to farm/ household, the drying process and the shelling and cleaning operations.

2.3 Theoretical and Analytical Frameworks

This study was based on the rational choice theory, also known as the choice theory or rational action theory. It provides a framework for understanding and modeling social and economic behavior (Lawrence and Easley, 2008). The theory attempts to explain what will happen when individuals are faced with a situation where they have to make a choice; example when farmers have to choose between alternative grain storage techniques. The theory borrows the assumption from economic theory that all individuals are rational beings. Farmers are assumed to be rational in their choices and put in practice the effective ways to safeguard food security, improve standard of living, income and profit maximization. Rational choice theory simply defines rationality as individuals such as farmers act to balance costs and risks against benefits to arrive at action that maximizes their personal advantages (Mitton, 1953; Okoruwa *et al.*, 2009).

Rational choice models assume that farmers' joint behavior result from individual actions alone with no role of institutions (Burns and Roszkowska, 2016). The models are used in choice problems (agricultural and other fields) to represent the selection of one among a set of mutually exclusive alternatives. Analytical approaches used in choices are binary logit model, multinomial logit model (MNL), multinomial probit model and nested logit models. The set of alternatives in these models must be exhaustive, mutually exclusive and finite (Hensher *et al.*, 2000).

Several analytical approaches have been developed to analyze farmers' choices of agricultural techniques. Non-parametric and parametric approaches have been used to investigate choice problems of techniques. According to Bontemps (2009), consumer choices can be modeled and predicted through the estimation of conditional probability distribution functions in a kernel non parametric framework. This framework can be implemented with a binary choice variable and both, continuous and discrete explanatory variables.

Parametric approaches commonly used to analyze choices are logit, probit, the linear probability models and multinomial logit and probit models. In the case of dichotomous dependent variable such as choices between a traditional technique and improved technique measured in nominal dummy variables, the linear probability model, the logit model and the probit model are applied. The linear probability cannot be constrained between 0 and 1 and therefore cannot be used (Amemiya, 1981; Wittink and Leeflang, 2000). The binary decision also produces a non-linear response and thus violates the assumptions of the linear regression model. As a result, a probability model based on a cumulative frequency distribution is used. The probability functions used for the probit and logit models are based on the normal distribution and on the logistic distribution functions respectively and they are bounded between 0 and 1 and they exhibit a sigmoid curve.

According to Acheampong (2015), probit and logit models have been used in empirical studies to capture the influence of socio-economic variables on farmer's adoption decisions. Both the multinomial logit and or probit analyses have been extensively used in social research involving more than two dependent variables (Tesfaye *et al*., 2003; Okoruwa *et al.*, 2009). Maboudu *et al*. (2000) used multinomial logit analysis model to assess the combined effect of three kinds of variables: farmers' social economic factors, technology characteristics and the farm specific factors on the use of four types of improved clay storage. Okoruwa *et al*. (2009) used a multinomial logit model to examine the post-harvest choices of grain storage techniques and pesticides use by farmers in South-West Nigeria. MNL models have also been applied in climate change studies. For example, Nhemachena and Hassan (2007) employed the multinomial logit model to analyze factors influencing the choice of climate change adaptations conditions.

2.4 Costs and Benefits of Grain Storage Techniques

A study by Adetunji (2009) conducted on economics of maize storage techniques by farmers in Kwara state, Nigeria analyzed three categories of storage structures. The benefit of using local (LS), semi-modern (SMS), and modern storage (MS) among maize farmers and traders was examined using a budgetary, partial budget, marginal analysis and gross margin. Findings revealed that the modern storage had the highest incremental gross margin compared to the control category (no storage). Another study by Oledajo (2016) employed the profitability analysis of various storage techniques used in Osun state. The most used technique in the area was the crib and it was the most profitable followed by metal drums, jute bags, open platform and the least was elevated ban technique.

Nduku *et al*. (2013) also conducted an economic comparative study of ten storage techniques in Kenya and a cost benefit analysis was employed to evaluate the viability of grain storage structures. Findings indicated that apart from the in house storage and traditional cribs, the BCR of the other structures (the metal silos and traditional granaries) was greater than one. The NPV at 15% discount rate ranged from Kshs 25 to Kshs 40 for a kg stored in traditional granary and metal silo respectively.

To the best of author’s knowledge, published empirical studies on the economics of traditional and modern grain storage techniques in Tanzania are scarce despite the wide use of traditional techniques and the increasing use of hermetic techniques. The study employed cost benefit analysis of project worth approach to determine and compare the costs and benefits of various storage techniques in Kilosa district, Tanzania so as to contribute to the identified gap of knowledge.

2.5 Farmer's Perception on Effectiveness of Grain Storage Techniques

A study by Midega *et al.* (2016) on farmers' knowledge, perceptions and practices on managing storage pests of maize in Kenya used a three point Likert scale; 1= Not severe 2=Moderately Severe and 3=Very Severe to understand the perceived severity of storage pest attacks on maize. Farmers identified nine different maize storage pests and severity of attack was rated. Chi square and one way analysis of variance (ANOVA) were conducted to assess any difference with regard of farmers' perceptions on pests and their management practices. Another study by Maonga *et al.* (2013) on adoption of metallic silos in Malawi examined farmers' perceptions on metallic silos. Results showed that farmers perceived metal silos as more effective, more secure but more expensive than their common indigenous storage techniques.

Another study by Abass *et al.* (2014) on comparison of post-harvest storage techniques in Tanzania involved farmers rating the storage techniques based on how they perceived them to be effective. In the study, farmers rated hermetic storage techniques without insecticide application (metal silols and PICS) as most effective ways of controlling storage pests.

Based on the researcher's knowledge, little is known about farmers' perception on the effectiveness of traditional and modern grain storage techniques in reduction of storage losses in Tanzania. In most studies, farmers are reported to perceive stored crop losses could be minimized by employing relevant management technologies but their perception on the effectiveness of each of the technologies in reducing stored crop loss is not addressed. This study used a five point Likert scale ranging from extremely effective to extremely ineffective to establish farmers' perceptions on the effectiveness of grain storage techniques in Tanzania.

The variables obtained from perception analysis can be combined to form an authentic measure of factors. Some studies have used principal component analysis (PCA) to reduce a number of variables through condensing them into smaller components while preserving as much information as possible. Negatu and Parikh (1999) in their study on the impact of perception and other factors on the adoption of agricultural technology in Ethiopia used PCA to reduce eight perceptions on adoption of wheat to two components to be included in the regression. Principal component analysis was also by Migwi (2012) in his study on farmers' perceptions of and willingness to pay for Aflasafe KE01 in Kenya to reduce four perceptions on the use of Alfasafe KE01 into three components.

The use of PCA assumes interval data that is multivariate and normally distributed. Kim and Mueller (1978) however justified the use of ordinal data such as Likert scale in the condition that PCA is used to find general clustering of variables for exploratory purpose and also if the variable correlations are believed to be less than 0.6 (Migwi, 2012). This study also used PCA to condense the perception variables from Likert scale responses to fewer parameters that were unrelated.

2.6 Determinants of Farmers' Choice of Grain Storage Techniques

Determination of effectiveness of storage techniques can define the scale of losses and subsequently farmers' ability to undertake successful inter-seasonal choices. A study by Maonga *et al*. (2013) on farmers' adoption of storage techniques in Malawi revealed that age, education, farm size and access to agricultural extension were significant factors that determined farmers' choice of metallic silo. Another study by Adefemi (2016) applied a logit regression model to determine factors influencing farmers' storage decisions. The choice of improved maize storage systems among farmers was strongly influenced by the level of education, trainings, farmers' beliefs and attitudes and household income. Although farmers had knowledge on improved grain storage systems, it did not influence their choice decisions. Despite of the use of both, traditional and hermetic storage techniques in Kilosa district, determinants of farmers' choices of the techniques are yet to be known. This study employed a multinomial logit model to determine factors affecting farmers' choice of a particular storage technique in Kilosa district in Tanzania.

2.5 Conceptual Framework

Based on the theory of rational choice that is a foundation of this study, farmers are assumed to be rational and will choose a storage technique that will balance costs and risks to maximize their personal advantages. Theoretical and empirical literatures indicate that farmer's choice of a given grain storage technique is influenced by demographic and socio-economic factors. This can be conceptualized as follows.

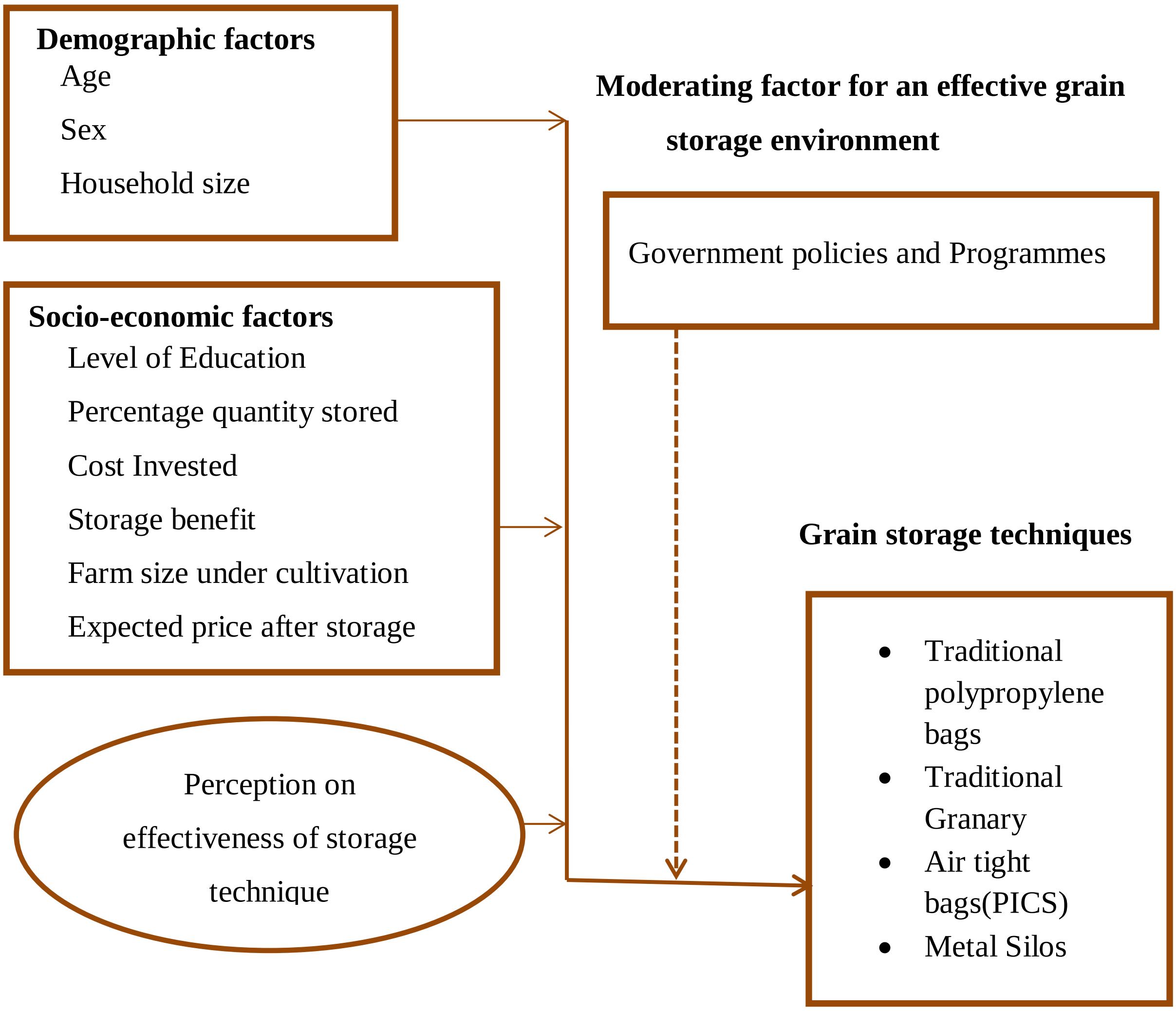

Figure 1: Conceptual framework

Source: Modified from Achieng (2014)

Figure 1 is the conceptual framework representing the interplay among variables that were used in the models of this study. Conceptualized independent variables that influence farmers' choice of grain storage techniques fall under three categories that is under demographic, socio-economic factors and farmers perceptions. From the demographic factors, the choice of storage technique is expected to be affected by the age of household head. According to Bokusheva *et al.* (2012), the probability of choosing an improved storage technology declined with age of household head. Similar results obtained from findings of other empirical studies (Barham *et al.*, 2004; Ersado *et al.*, 2004) suggest that older people experience declining cognitive and learning abilities thus become more reserved regarding acceptance of innovations. Sex of household head is expected to determine household's choice of grain storage techniques. According to Atibioke (2012), more men engage in farming activities and decision making than women thus affecting their choices and adoption of farm technologies. Household size is also expected to affect the choice of grain storage technique as households with large number of people are expected to have more food needs than small sized households. According to Adetunji (2007), increase in household size will cause a decrease in the use of modern storage techniques.

Socio-economic factors also affect farmers' choice of grain storage techniques. Educated household heads are aware of risks of grain loss associated with traditional storage thus are more likely to choose modern storage techniques. A change in the percent of quantity of grain stored is also expected to affect the choice of grain storage techniques. According to Sekumade and Akinleye (2009), an increase in the amount of grain stored will increase the use of semi modern storage technologies such as improved traditional granary. Modern storage technologies are most likely used when stored grain is less due to high costs involved in acquiring them. Considering investment costs, high investment costs cause farmers to take time to earn before they can purchase storage facilities thus increasing the use of traditional storage since these do not involve high costs in constructing/purchasing them (Kimenju *et al.*, 2010). Another variable that was expected to affect choice of grain stores was expected benefits from grain storage. According to Basorun and Fusakin (2012), the choice of storage technology is rationalized through derived benefits against various limitations.

Farm size is also expected to affect farmers' choice of grain storage techniques. Larger farm areas would likely lead to higher production, other factors remaining constant. Households with high harvested volume of grain would diversify the storage techniques so as to avert risk of loss (Chitja-Thamanga *et al.*, 2004). Expected price after storage is also expected to affect farmers' in their decisions on the storage technique to use. This is expected because farmers would hold grain for a longer period if price is expected to rise thus increase the use of modern storage techniques as these store grain for a longer time. Perception on grain storage techniques is another variable that is expected to influence farmers in their choices of grain stores. According to Achieng (2014), farmers may subjectively evaluate cultural aspects of new storage technologies differently and therefore it is important to understand farmers' perception in designing and promoting new technologies.

The independent variables interplay with moderating variables in this context in order to enhance effective grain storage. Moderating variables in this case are government policies and programmes. With proper government reforms in place, improved grain storage techniques are introduced and promoted among rural farmers, thus reduction of post-harvest losses to smooth availability of food supply at household level but also contribute to income generation through deferred sales of stored produce. The existence of government arms such as Cereal and other Produce Board (CPB) work in collaboration with the Ministry of Agriculture (MOA) to enhance effectiveness and efficiency during pre and post-harvest seasons through implementing programmes and projects in the rural areas of Tanzania that create awareness and educate farmers on post-harvest grain management.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Description of the Study Area

3.1.1 Location of the study area

The study was conducted at Kilosa district in Morogoro region. The district is located at the East central Tanzania, 300 km West of Dar es Salaam and is bounded by latitude $5^0$55'and $7^0$53' South and longitudes $36^0$30' and $37^0$30' East. Kilosa borders Mvomero district to the East, Kilombero and Kilolo districts to the South, Kiteto (Manyara region) and Kilindi (Tanga region) to the North; and Mpwapwa district (Dodoma region) to the West. The district covers a total area of 142 545 square kilometers, of which the largest area of 536 590 ha is suitable for agriculture in cultivation of cash and food crops. According to the Population and Housing Census for United Republic of Tanzania (PHC, 2012) the district has a population of 438 175 where 218 378 are men and 219 797 are female.

3.1.2 Selection of the study area and justification

Kilosa district was selected because it was one of the two study districts in the Trans-SEC project which was conducted in 2016. The project aimed at innovating pro-poor strategies to safeguard food security using technology and knowledge transfer. Data collected from this survey was used in this study. Kilosa district is also mentioned among the districts with great potential for Tanzanian economic development (Swai, 2016).

3.2 Research Design

The study employed a cross sectional research design where data was collected at a single point in time. The targeted population was farmers in Kilosa district who were involved in the Trans-SEC project which had phased out in the 2016/2017 cropping season. The project created awareness and promoted modern improved storage techniques therefore farmers used both, traditional and hermetic techniques for grain storage.

3.3 Sampling Procedure and Sample Size

The study employed a multistage sampling technique whereby in the initial stage, Kilosa district was purposively selected for data collection in the study since it was among the districts involved in the project. In stage two, Ilakala and Changarawe villages in Kilosa were selected randomly among the list of project villages. From the two villages, a total of 153 farmers, 76 farmers from Ilakala and 77 from Changarawe village were randomly selected from a list of farmers who were in the Trans-SEC research project.

The sample size was determined by Cochran's formula. According to Miaoulius and Michener (1976), three criteria need to be specified in order to determine appropriate sample size. These are level of precision, degree of variability in the attributes being measured and the level of confidence or risk. Cochran (1977) established a formula that considers the three criteria as shown in equation 1.

The Cochran's formula

$$n = \frac{z^2 * p * q}{e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where;

n = sample size, z=the abscissa of the normal curve that cuts off an area α at the tails (confidence level), e= acceptable sampling error (level of precision), p= the estimated proportion of an attribute that is present in the population, q=1-p. The confidence level in this study was set as z=1.96 (at α=0.025), while the degree of precision e=0.05.Since the variability in proportion of the population of farmers who actually store grain is not known, the degree of variability was assumed to be maximum at p=0.5 and hence q=0.5.

$$n = \frac{(1.96^2)(0.5)(0.5)}{0.05^2}$$

$n \approx$ 384 respondents

However, the sample size of 153 respondents was taken due to financial and manpower constraints. A study by Adefemi (2016) on economic analysis of cereal grain storage technique in Osun state used a sample of 150 maize farmers which also conforms to the sample size used in this study.

3.4 Data Collection Methods

Both primary and secondary data were used in this study. Primary data was collected using a survey questionnaire and interviewing farmers whereby both qualitative and quantitative data on their socio-economic and economic characteristics such as age, education, farm size, type of storage used, cost of grain storage techniques and price of grain after storage were gathered. The questionnaire contained both closed and open ended questions. The study also used secondary data which was collected before phasing out of the Trans-SEC project in the study area.

3.5 Data Analytical Framework and Model Specification

3.5.1 The cost benefit analysis

Benefit costs analysis is a financial measure of project worthiness. For this study, the analysis was done for two periods where a household either sold grain after harvest or stored for future sell. The benefit of using an improved hermetic storage technique was measured by the value of food grain saved from loss in store as a result of the improvement of techniques. Direct and measurable benefit was obtained from the sale of grain before storage or after average months of storage. These were valued at prevailing market prices during the survey.

The costs incurred by farmers included investment costs and operating costs. Investment costs are costs of investing in the storage structure. Operating costs considered were the costs of labour (both family and hired), transportation costs, repairs, maintenance, insecticide costs and storage loss costs. Fixed costs for durable container considered were depreciation of storage techniques and capital costs. Calculation of costs and benefits was as shown below.

The metal silo is a hermetic storage container with a capacity of storing grain from 100kg-3000kg. For this analysis, metal silo was considered to be 500kg. Annual costs of storage techniques were calculated as shown in equation 2.

Total Annual Costs= Capital Costs+ Depreciation + Variable Costs…………..……… (2)

Capital costs can be defined as the average interest charged on the silos. It is calculated at 15% interest rate, which is the rate charged on short term bank loans multiplied by average capital value. The average interest was calculated per kg per year as shown in equation 3.

Average Capital Value= (Cost Installed-Salvage Value)/n…………………………… (3)

Where n is the useful life of the storage technique. Depreciation of assets (traditional granary, metal silos and hermetic bags) was calculated using the straight line method as expressed in equations 4, 5 and 6. The useful life of the traditional granary and metal silo was assumed to be 11 and 15 years respectively, while that of hermetic bags was 3 years. The salvage value is assumed to be 5% of the purchase price, which conforms to a similar study by Shively (2000).

Depreciation over n years= Purchase price-Salvage price depreciated over n years…..(4)

$$Depreciation\ per\ annum = \frac{Depreciation\ over\ n\ years}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where n is the useful life of the storage technique.

$$Depreciation\ per\ kg\ per\ year = \frac{Depreciation\ per\ annum}{Amount\ in\ kgs\ per\ storage\ technique} \ldots\ldots\ldots. (6)$$

Total annual costs= Capital costs per kg per year + Depreciation Costs per kg per year + variable costs per kg per year……………………………………...…... (7)

Benefits from grain storage were calculated as shown in equation 8.

$$B_t = Q * P_t * \frac{L}{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where B_t is the financial Benefit obtained in year t, Q is Quantity of grain stored by farmer (kgs), P_t is the farm price at the time of selling grain and L is the percent of loss saved through using an improved storage technique.

To compute discounted measures of project worthiness (NPV and BCR), streams of benefit and costs of grain storage techniques are discounted over a given number of years. The choice of the discount rate was taken as the commercial banks' rate for short term loan advances. For this study, the rate of 15% which is the opportunity cost of investing in grain storage techniques was used. The choice of number of years to be included for all storage techniques was based on the average useful life of the metal silo, which is 15 years. Recurring costs of traditional storage bags and modern air tight bags were accounted for in the discounted cash flow after every one and three years respectively. Walsh *et al.* (2014) on their research about hermetic storage techniques reported that the average life span of the PICS is 2–3 years, which means that they must be replaced more frequently than most local containers. This technique conforms to a similar study by Shively (2000). Net Present Values of investing in either of the storage techniques and

Benefit Cost Ratios of storage techniques were calculated from the formula adopted from Ashimogo (1988) as shown in equations 9 and 10.

$$NPV = \sum_{t=1}^{t=n} \frac{B_n - C_n}{(1+i)^n} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9)$$

$$BCR = \sum_{t=1}^{t=n} \frac{B_t}{(1+i)^n} / \sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots (10)$$

Where B_t is the financial benefit obtained in year t (Tshs), *NPV* is the Net Present Value of the storage technique (Tshs), *BCR* is Benefit Cost Ratio of the storage technique, C_t is the financial costs incurred in operating stores in year t(Tshs), *i* is the discount factor (assumed to be 15%, that is 1.3% per month as a rate of banker’s short term advances), *t* representing the year when benefits and costs are evaluated, that is t=1…..n and *n* is the number of years the project is assumed to last that is the life span of the storage structure.

Future flows of costs and benefits assumed a constant price as a way to deal with inflation. By use of constant prices the main assumption is that inflation will affect all costs and benefits equally at specified period of time. The project is profitable or feasible if the calculated NPV is positive when discounted at the opportunity cost of capital (Gittinger, 1982; Poudel *et al*., 2009).

3.5.2 Sensitivity analysis

This measure is done to determine what might happen to the earning capacity of storage projects if events differ from prior estimations made about them during planning. It considered the prices and costs of storage techniques after average period of storage. A percentage change in prices and costs of storage between harvesting period and the period after storage was calculated for each household and the average percentage change in price and costs were 30% and 20% respectively.

The test was therefore performed by assuming first a 20% increase in cost and 30% fall in prices then a 20% fall in cost and 30% increase in prices for all four storage techniques involved in the study. This test was performed to allow a comparison between traditional and modern storage techniques.

3.5.3 Farmers' perception on the effectiveness of storage techniques

According to Apata *et al.* (2013), local perceptions cannot be estimated by models. This study used a five point Likert scale to measure farmers' perceptions on effectiveness of grain storage techniques in crop loss reduction. This was done by scale ranging from extremely effective, effective, undecided, ineffective and extremely ineffective to fit respondent feelings. Bernard (1994) asserts that Likert scale type of interview items results in a single score that represents the degree to which a person is favorable or unfavorable in response with respect to question asked. Therefore, perception of farmers on effectiveness of grain storage techniques was done by looking on perceived ability of the identified grain storage technique to reduce crop loss, prevent insect infestation and incidence of longer storage period. So to say, different aspects related to attributes that make a particular storage method effective in the study area were focused on.

Descriptive statistical tools (percentages and frequencies) were used to summarize the information gathered and show respondents' perception. Chi-square test was applied to test the proportions of farmers with positive perception to those with negative perception for a particular storage technique.

PCA is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into set of values of linearly uncorrelated variables known as principal components (Rao, 1964). The principal components explain maximal amount of variance among the set of the original data. Each principal component is usually a linear weighted combination of the initial variables, with coefficients equal to the eigenvectors of the correlation or covariance matrices (Lwayo and Obi, 2012: Migwi , 2012).

The principal components are ordered in such a way that the first component accounts for the largest possible variance in the original dataset. The second component account for the second greatest variance that is not accounted by the first and is completely uncorrelated with the first principal component and so forth (Rao, 1964). According to Rao (1964), PCA is the most successful method of conducting factor analysis. The first principal component can be computed as shown in equation 11.

$$PC_n = f\ (\beta_{ni} X_i \ \dots\dots\dots\dots\dots\dots \beta_{1k} X_k) \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.....(11)$$

If the number of principal components is greater than 1, say n numbers, then each principal component will be a continuous variable or quantity related to the products of the values of the constituent variables and their respective weightings or component loading. The relationship is an additive one hence the value of the principal component can be obtained by addition of the products as shown in equation 12

$$PC_n \ = \ f\ (\beta_{11} X_1 + \beta_{12} X_2 + \cdots \dots\dots\dots\dots\dots\dots \beta_{iK} X_k) \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(12)$$

Where PC_1 is the first principal component, β_{1k} is the regression coefficient for the *kth* variable that is the eigenvector of the covariance matrix between the variables, and X_k is the value of the *kth* variable.

Principal component analysis (PCA) using statistical package for social sciences (SPSS) was used to reduce the number of the variables (obtained from Likert scale responses) but still reflect a large proportion of the information contained in the original dataset. Components extracted from PCA analysis were included in the multinomial regression analysis as variable(s) for farmers' perception to determine factors that influence choice of grain storage techniques. Principal components with Eigen values greater than one were selected for analysis (Owino *et al.*, 2012). The Kaiser-Meyer-Olkin measure of sampling adequacy considered was that above the threshold of 0.5. Any value below 0.5 is considered miserable according to Everitt and Hothorn (2011). Varimax rotation which is a form of orthogonal rotation strategy was used.

3.5.4 Determinants of choices of storage techniques

Choices of alternative storage techniques available to farmers are naturally unordered. In such a condition, unordered choice models such as the multinomial logit and probit models can be used (Green, 2000). According to Fentie and Rao (2016), the multinomial probit model is less restrictive than multinomial logit model however; a multinomial probit model has many computational expenses. Therefore, the study adopted the multinomial logit model to analyze factors for the choice of grain storage techniques. The model assumes a set of alternatives; in this case the alternative storage techniques to be exhaustive, mutually exclusive and finite. Therefore, the analysis excluded farmers who used more than one storage technique. The multinomial logit model was expressed as shown in equations that follow

Let P_{ij} represent the probability of choice of any given grain storage technique by farmers as shown in Equation 13;

$$P_{ij} = \beta_0 + \beta_1 X_1 + \ldots + \beta_k X_k + e \quad \ldots\ldots(13)$$

Where *i* takes values (1, 2, 3, 4), each representing the choice of grain storage technique (polypropylene bags =1, Traditional granaries =2, Hermetic Bags=3, Metal Silos=4). *Xi's* are factors affecting choice of a grain storage technique, β are parameters to be estimated and *e* is randomized error. With *j* alternative choices, the probability of choosing technique *j* is given in equation 14.

$$Prob(Y_i = j) = \frac{e_{zj}}{\sum_{k=0}^{j} e_{zk}} \text{ ....(14)}$$

Where Z_j is a choice and Z_k is alternative choice that could be chosen (Greene, 2000). The model estimates are used to determine the probability of choice of a grain storage technique given j factors that affect choice X_i. With a number of alternative choices log odds ratio is computed as shown in equation 15.

$$\ln\left(\frac{P_{ij}}{P_{ij*}}\right) = \alpha + \beta_1 X_1 + \cdots + \beta_k X_k + e_k \text{ ....(15)}$$

Where, P_{ij} and P_{ik} are probabilities that a farmer will choose a given storage technique and alternative technique respectively. $ln\left(\frac{P_{ij}}{P_{ij}}\right)$ is a natural log of probability of choice j relative to probability choice k, β is a matrix of parameters that reflect the impact of changes in X on probability of choosing a given storage technique, α is a constant and e is the error term that is independent and normally distributed with a mean zero. The parameter estimates of the multinomial logit model provide only the direction of the effect of the independent variable on the dependent (response) variable but do not represent either the actual magnitude of change nor probabilities. The marginal effects or marginal probabilities in equation 16 are functions of the probability itself and measure the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable from the mean (Green, 2012). Marginal effects of the attributes on choice are determined by getting the differential of probability of a choice and it is as given in equation 16.

$$(\delta) = \frac{\partial P_i}{\partial X_i} = pi(\beta_j - \textstyle\sum_k^j P_k \beta_k) = P_i(\beta_j - \beta) \text{ .... (16)}$$

The Multinomial logit model is as given in equation 17

$$P_{ij} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n + \mathcal{E}_i \text{ .... (17)}$$

The choice of grain storage technique is then given as shown in equation 18;

$$P_{ij} = \beta o + \beta_1 age + \beta_2 gend + \beta_3 edu + \beta_4 exp + \beta_5 invcost + \beta_7 ben + \beta_7 effper + \beta_8 hhsize + \beta_9 fms + \beta_{10} psold + \beta_{11} cprod + \beta_{12} pcons + \varepsilon_i \dots\dots\dots\dots \quad (18)$$

3.5.5 Description and prior expectations of signs of variables influencing choice of storage techniques

The description of all variables in the model (18) and their expected signs are listed in Table 1 followed by reasons behind their expectations.

Table 1: Description of variables and their expected signs in MNL regression model

Independent Variable	Description	Measurement	Expected sign
SEX_Dummy	Sex of household head	1 if a HH is Female 0 if otherwise	-
AGE	Age of household head	Years of HH	+
EDU_Dummy	Education of respondents (Secondary education and more =1, primary and non-educated=0)	Level of education	+
HSIZE	Household size	Count	+
CPROD	Number crops produced	Count	+
INV	Investment Cost	TShs	-
BEN	Storage benefits	TShs	+
EFFPER	Perception on effectiveness of technique	Percentage	+
FMS	Farm size	Acres	+
P_CONS	Percent stored for consumption	Kilograms	-
P_SELL	Percent stored for sell	Kilograms	+
EXP	Expected price after storage period	TShs	+

Sex of the household head is expected to have a negative sign. Female headed households are expected not to have enough grain to feed their families and to store for later consumption. Women in most rural societies are likely to have no access to resources such as land thus producing less with the help of their children. Age of head of household is expected to have a positive sign. As age increases, households become exposed to more grain storage techniques thus choose the technique that best suits their needs. Older household heads are likely to choose traditional storage techniques as they might be unwilling to try new techniques because they are more expensive and more complicated to use. Unlike adult household heads, younger households are willing to adopt different types storage techniques.

A positive sign is also expected for level of education of household head. Educated household heads are expected to have a wider choice of grain storage techniques than non-educated ones because they are aware of the benefits and risks of grain losses associated with various types of storage techniques than non-educated ones. Family size is expected to have a positive impact on the choice of stored grain techniques. Families with large household size are expected to be more flexible in their choice of grain storage techniques than households with relatively smaller household size. Unlike in small families, household heads of larger families might be interested in techniques that will store a large amount of grain for a longer time at minimum costs.

With regards to the number of crops produced, a positive effect on the choice of grain storage techniques is expected. As the number of crops cultivated increases, households are likely to store grain independently unlike households with only one type of crop such as legumes where crop may be stored in a single structure or consumed. The higher the investment cost of a given storage technique, the less chance it stands to be chosen. Higher investment costs for grain storage techniques make it difficult for households to afford buying them thus a negative sign is expected for this variable. Storage benefit is expected to have a positive effect on the choice of stores. The higher the expected benefit accrued to a given storage technique the higher the chance it stands of being used.

Farmers' perception on the effectiveness of grain storage techniques in reduction of crop losses is also expected to have a positive effect on choice of technique. Any improvements in technology will only be attractive to farmers if it is perceived to be less risky in terms of storage crop losses. Farm size is expected to have a positive sign on farmers' choice of grain storage techniques. Households with large farms are likely to harvest more grain compared to those with relatively small farms, other factors assumed constant. Households will then need to store grain for other uses. Other factors remaining constant, small sized farms yield less grain thus households may not have enough to consume and store.

Percentage of grain stored for consumption is expected to have a negative impact on farmers' choice of grain storage techniques. The percent of grain stored for consumption is not expected to exceed the amount stored for sell thus farmers are likely to use a single storage structure and not find it meaningful to decide to choose other storages for such purpose. Percentage of grain stored for sell is likely to have a positive impact on farmers' choices as they have a motive to store grain for a longer time and still maintain its quality so as to sell at higher prices during period of scarcity. The expected price after storage is likely to have a positive impact on the choice of grain storage techniques. Farmers expecting a higher price are likely to store more grain thus choosing a storage technique that will store grain at a longer period while maintaining its quality.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Chapter Summary

The study aimed at accessing the economics of grain storage techniques for small holder farmers in Kilosa district in Tanzania. Specifically, the study intended to analyze the costs and benefits of grain storage techniques, analyze farmers' perception on the effectiveness of grain storage techniques and to identify determinants of choice of grain storage techniques. The study findings as presented in this chapter will first present the summary of household characteristics and explain how they relate to grain storage followed by addressing the first research question which asks what are the costs and benefits associated with the use of grain storage techniques by computing the NPV and BCR of each storage technique, discounted for 15 years at 15% interest rate. Hypotheses for the second and third objective which state; There is no significant differences in farmers perception on the effectiveness of grain storage techniques and socio-economic factors do not influence the choice of grain storage techniques will then be tested with the chi-square test and multinomial logistic regression respectively.

4.2 Household Characteristics of the Respondents

4.2.1 Gender of the household heads

Table 2 presents a summary of gender of heads of sample household in the study area. More than half of the households, that is 75.8% are male headed while 24.2% were female headed households. This has implications on the production and storage decisions where most of decisions are made by men. Even though many households were male headed, storage activities including use of hermetic storage techniques tend to be operated by females. According to SDC (2013), managing hermetic storage techniques by women helped them to improve their status and self-esteem.

4.2.2 Age of respondents

Results in Table 2 gives a summary of ages of respondents interviewed across the study area. Most of the farmers were middle aged ranging between 25-44 years with 47.7% followed by the age group 45-65 with 44.4%. Few respondents fell in the groups under 25 and above 65 where only 1.3% and 6.5% of respondents were in these groups respectively. This means that majority of grain farmers were within the working age group. This implies the roles that pertain to the working group in any society. Mlambiti (1994) shows that age structure can be used to facilitate an understanding about labor potential of a specific population and Golledge (2006) explains that age determines individual maturity and ability to make rational decisions.

4.2.3 Education level of respondents

According to Atibioke *et al*. (2012), the level of farmers' education and occupation play a very significant role in storage decisions. Results presented in Table 2 below indicate that more than half of farmers attended formal education where 59.9% attended primary school, 17% had secondary school level of education (both ordinary and advanced secondary levels) and 5.2% attended the university and 18.3% did not attend any formal education.

Table 2: Socio – economic characteristics of farmers in Kilosa district

Variable		Frequency	Percentage
Gender	Male	116	75.8
	Female	37	24.2
	Total	**153**	**100.0**
Age	<25	2	1.3
	25-44	73	47.7
	45-65	68	44.4
	>65	10	6.5
	Total	**153**	**100.0**
Education	Kindergarten/Madrassa	28	18.3
	Primary	91	59.5
	Secondary	26	17.0
	University	8	5.2
	Total	**153**	**100.0**
Farmer Experience	<10	53	34.6
	10-30	89	58.2
	>30	11	7.2
	Total	**153**	**100.0**
Extension Services	Yes	100	65.4
	No	53	34.6
	Total	**153**	**100.0**
Access to Credit	Yes	67	43.8
	No	86	56.2
	Total	**153**	**100.0**

4.2.4 Farmers experience in grain storage

Results from the study as presented in Table 2 above indicate that more than half of the respondents that is, 58.2% of the farmers had experience of between 10-30 years. Thirty five percent of farmers had less than 10 years of experience in grain storage while very few farmers had more than thirty years of experience in producing and storing of grain. This indicates that most of the farmers were experienced. According to Prebenshen *et al.* (2018), grain producer with many years of working history is more experienced, and thus can make reasonable arrangements effectively to avoid grain loss.

4.2.5 Access to extension services

From the study, most of the farmers had access to extension services, as shown in Table 2. Table 2 reveals that, 65.4% of farmers received extension services in the year 2016/2017 while 34.6% of farmers had no contact with extension farmers. This implies that most of the farmers had a chance to get educated on the proper methods of grain management after harvest including effective grain storage techniques.

4.2.6 Access to credit facilities

Results from table 2 indicate that 56.2% of farmers had no accessibility to credit while 43.8% of them had accessibility to credit from both, financial institutions like banks and non-financial institutions such as VICOBA. Credit is important for farm production and has an implication on grain storage activities as it facilitates purchases of storage facilities and accompanying requirements such as insecticides and materials for repair and maintenance of grain storage techniques.

4.3 Farm Characteristics

4.3.1 Farm size

Results from the study indicated that the average farm size of farmers in the study area was 2.99 acres with a minimum of 1 acre and a maximum of 11 acres. Results also show that most farmers, 86.8% had less than 3 acres of land cultivated in 2016/2017 while 13.2% had more than 3 acres of land. This implies that, most of the farmers are smallholder farmers following the definition of a smallholder farmer by FAO (2015).

4.3.2 Average quantity of grain produced per household in 2016/2017

Farmers in the study area produced mostly legumes and cereals as shown in the Table 3. Maize was the most produced crop with the highest standard deviation implying that data on maize production is spread out over a large range of values. Legumes (beans, cowpeas and pigeon peas) were produced in small amounts and very little was stored for consumption purposes only. This fall in production was attributed to a tragic fall in prices of legumes especially cowpeas and pigeon peas in the respective season (2016/2017).

Table 3: Average quantity in kilograms of grain produced per household in 2016/2017

Type of crop	n	Minimum	Maximum	Mean	Std. Deviation
Maize	152	200	21600	1617	981
Beans	11	60	480	206	127
Cowpeas	16	20	1800	280	428
Pigeon peas	25	4	1800	403	392

4.3.3 Grain storage techniques

Polypropylene bag is the most commonly used storage technique with more than half (83%) of the farmers using it as shown in figure 2. Traditional granaries (Kihenge) are the least used storage facilities with only 2% of farmers storing grain in it while hermetic storage techniques are used by 15% of farmers in the study area. This could be attributed to inhibited availability and accessibility of hermetic storage techniques in the study area. Most of these facilities were brought to the villages with development projects and during the projects' life span; the storage techniques were easily accessible, available and subsidized to make them affordable to farmers. The storage techniques became hardly accessible and expensive when these projects phrased out.

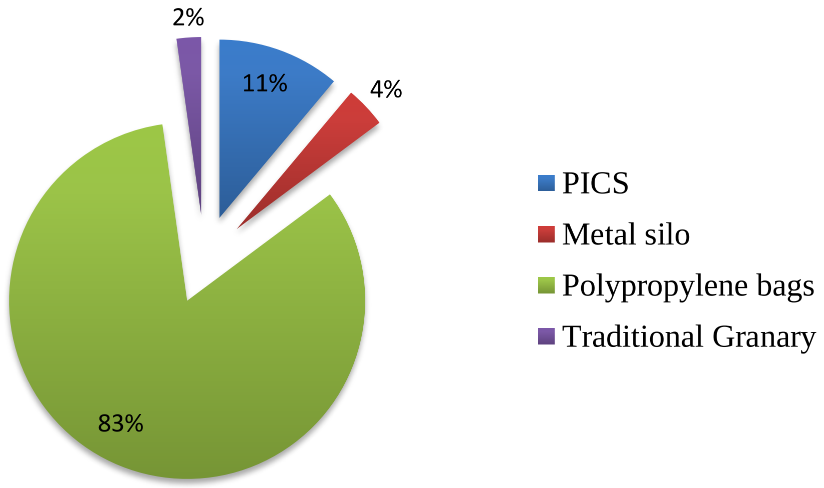

Figure 2: Percentage use of grain storage techniques in the study area

4.3.4 Average quantity of grain stored per storage technique in 2016/2017

Average amount of each grain stored in each of the four storage techniques was as presented in Table 4. As it can be seen, maize was the most produced and stored cereal grain in the last cropping season. Legumes were stored mostly for household consumption purposes only. Results in Table 4 also show that farmers stored maize in all storage techniques while they hardly used other types of grain storage techniques for storage of legumes except for polypropylene bags. For this reason, the benefit cost computation of grain storage techniques in this study did not consider storage of legumes.

Table 4: Average quantity of maize and legumes stored per storage technique

Storage Technique	Crops	n	Mean	Median	Std Deviation
Traditional granary	Maize	3	975	1 020	580
	Legumes	1	200	200	-
Metal silo	Maize	4	5137	5 400	2486
	Legumes	1	280	240	69
Polypropylene bags	Maize	112	161 125	1 020	2228
	Legumes	16	720	290	840
PICS	Maize	16	1221	660	882

4.3.5 Utilization of stored grain in the survey villages

A percentage of harvested grain is sold soon after harvest. About 30% of total grain harvested was sold immediately after harvest. Instant sales of grain after harvest were due to temporary but immediate liquidity preferences to meet various obligations in the absence of or limited sources of cash. However, most farmers (about 70%) store maize for sell and consumption later. More than 50% stored grain for securing their future food needs. The share of quantity of bags stored for sell, seeds and other uses was 30%, 11% and 1% respectively. According to Ashimogo (1988), consumption is the principle purpose of storage only in case of smallholders and it is overshadowed by sale in case of large scale farmers.

Storage economics utilizes data on quantity stored for consumption and for sell to obtain costs and benefits accrued to alternative storage techniques respectively. Table 5 summarizes the average amount of maize stored for consumption and for sell for each storage technique used in the study area. The average quantity of maize grain stored in hermetic techniques and the traditional granary for consumption was greater than the average stored for sell. This was not the case with polypropylene bags where farmers used the bags mostly for storage of maize for sell. This could be explained by the fact that maize stored in all stores except in polypropylene bags was not dusted for protection against insects. Farmers who used more than one storage structure sold maize that was stored with chemicals in traditional bags and consumed that which was not stored with chemicals in other storage techniques.

Table 5: Average maize stored for consumption and for sell per storage technique

Storage Technique	Quantity(kgs) stored for…	n	Minimum	Maximum	Mean	Std Deviation
Traditional granary	Consumption	2	360	1 200	640	400
	Sell	2	240	1 080	640	421
Metal silo	Consumption	3	300	500	383	75
	Sell	2	100	200	167	52
Polypropylene bags	Consumption	128	60	2 400	580	463
	Sell	110	120	2 400	645	492
PICS	Consumption	12	300	600	407	92
	Sell	4	100	500	258	131

4.3.6 Average storage period for maize grain per storage technique

Due to the seasonality nature of grain production, it is stored for a fairly long time. Results from Table 6 show that average grain storage period for consumption was the least for traditional granary (7 months) and highest for metal silos (11 months). Average period for sale was 8 months for polypropylene bags while it was 10 months for other techniques. It is thus clear that hermetic storage structures store grain for a longer period compared to traditional ones. Despite the advantage over traditional techniques, most farmers still choose traditional bags with insecticides over hermetic bags. This might be attributed to high purchase price of PICS and metal silos.

Table 6: Average maize storage period for consumption and sell per technique

Storage Technique	Months of storage for…	n	Minimum	Maximum	Mean	Median	Std Deviation
Traditional granary	Consumption	4	4	12	7	7	3.416
	Sell	4	4	10	7	8	3.402
Metal silo	Consumption	5	10	12	11	11	0.753
	Sell	5	9	11	10	10	0.894
Polypropylene bags	Consumption	128	1	12	10	11	2.287
	Sell	112	1	10	7	8	2.902
PICS	Consumption	16	4	11	10	11	1.817
	Sell	10	5	12	10	10	2.227

4.3.7 Marketing of stored grain

Farmers in the study villages used several sales options. The main market outlet for harvested grain was through the middlemen. More than half of the surveyed farmers sold maize at farm gate to middlemen (58%) while the rest sold to large traders, millers and neighbours (42%).The price with which grain was sold at was determined through negotiations between the buyers and farmers. Farmers sold from small amounts of 4 kilograms (*kisado*), 20 kilograms (*debe*) to 90-120 kilogram bags.

4.4 Costs Benefit Analyses of Maize Storage Techniques

To be able to make a sound financial decision, there is a need to compare return on investment of each storage technique. Conducting a cost benefit analysis of traditional and improved hermetic storage techniques enables farmers to know which financial benefits to plan for and costing an appropriate storage to suit the plan. Grain storage costs include both, fixed and variable costs. Fixed costs for grain storage techniques included in this study were depreciation and investment costs. Repair and maintenance costs, cost of chemicals, labor costs and storage losses of grain were computed as variable costs for grain storage. Since farmers indicated using no chemicals to protect maize grain in hermetic storage techniques, costs of chemicals were not considered as part of costs for PICS and metal silos, instead they were taken as part of costs for polypropylene bags.

This study considered four grain storage techniques, both traditional and modern hermetic facilities. Traditional techniques were polypropylene bags and traditional granaries (kihenge) while modern storage techniques considered were hermetic storage bags (PICS) and metal silos. Costs of purchasing each storage technique is discussed below.

4.3.1 Costs of storage bags

Traditional bags commonly used in grain storage are polypropylene bags. They usually come in different sizes ranging from 5 to 120 kilogram bags. The most common bags used in the study villages were 120 kilogram bags and price per bag ranged from 600 Tshs to 1 200 Tshs. Total costs of polypropylene bags per household were as shown in Table 7. Hermetic bags commonly used for grain storage were PICS (100kg) with average prices of 4 800 Tshs per bag. PICS are originally more expensive than polypropylene bags. For this reason, few farmers opted to use PICS in the last cropping season however with associated efficacy in storage loss reduction farmers are expected to adopt PICS.

4.3.2 Cost of traditional granary

The most common traditional granary used in the study area is the kihenge. Few farmers reported using this storage structure. Traditional kihenge is constructed from local materials such as mud, reeds and bamboo. Traditional granaries used in the study area varied in sizes depending on farmer's needs from 1 ton to 5 tons. Cost of constructing 1 ton size structure (8 bags) ranged from 35 000 Tshs to 45 000 Tshs with an average of 38 750 Tshs as shown in Table 7. These were costs for the local building materials.

4.3.3 Cost of metal silo

Metal silo is a modern air tight storage technique which was also adopted in the study villages. The useful life or duration of a metal silo is approximately 15 years. Farmers reported using the 500kg metal silo in which 80% stored maize for only food consumption while 20% used grain stored in silos for both consumption and selling purposes. Average cost of installing a 500kgs metal silo was 190 000 Tshs as shown in Table 7.

Table 7: Average purchasing/construction cost of storage techniques

Storage Technique	Capacity (kgs)	Average units per household	Average price (Tshs)	Average total costs
Traditional granary	1 tone(908kg)	1 kihenge (9 bags)	38 750	38 750
Metal silos	500kgs	1 Silo (5 bags)	190 000	190 000
Polypropylene bags	120kgs	14 bags	1 100	19 229
PICS	100kgs	5 bags	4 800	25 906

4.3.4 Maize storage loss

The amount of grain lost was calculated for every hundred kilograms stored in each storage technique. High storage losses were experienced by farmers using polypropylene bags as it is shown in Table 8. Despite the use of chemicals for preventing insect infestation in polypropylene bags, grain stored in the bags was easily affected by rodents, insects and molds especially when proper pre storage management practices were not followed at a proper time. Farmers using metal silo experienced the least post-harvest losses through storage. This implies that metal silo could be an important technology for enhancing food security particularly for small scale farmers in developing countries.

Table 8: Average quantity loss per 100 kilograms of maize for each technique

Type of Storage	n	Minimum	Maximum	Mean	Std. Deviation
Traditional granary	4	0.30	3.60	0.94	1.77
Polypropylene bags	113	0.91	24.04	1.36	2.69
PICS	14	0.03	2.40	0.52	.81
Metal silo	6	0.00	1.02	0.03	2.61

Percentage maize loss was also calculated for each storage technique as indicated in Figure 3 below. Percentage losses appeared to be the highest for maize stored with polypropylene bags while hermetic storage techniques had the lowest percent of maize loss. According to Shaban *et al.* (2015), maize grain stored in polypropylene bags is most likely to be attacked by insects or mold thus causing mycotoxin contamination to maize flour. Also, these findings conforms to a similar study by Nduku *et al.* (2013) where he reports that farmers using the traditional storage methods lost more than ten percent of their stored maize compared to the improved structures.

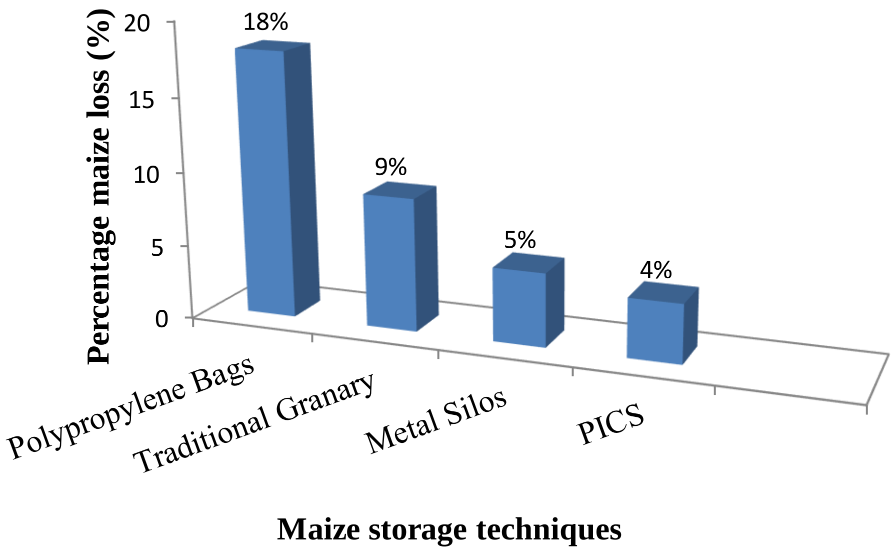

Figure 3: Percentage losses of maize stored in alternative storage techniques in 2016/2017

Results on percentage of maize loss reduced from using an improved storage technique were used to calculate benefit of improved storage techniques.

4.3.5 Reasons for grain loss during storage

Table 9 shows farmers' experienced causes of grain loss in storage. As shown in the table, most farmers experienced loss from insects followed by rodents such as rats and mice. The most common insects affecting stored grain in the study area were the weevils. Most farmers reported to use Shumba super dust chemical to protect their stored grain from being attacked by insects. Other stored grain insecticide used was the actellic super dust. Maize was dusted before being stored in polypropylene bags. Some farmers reported not to have experienced losses either due to the use of improved hermetic storage techniques or proper grain management practices before storage, as shown in Table 9. The most common reason for grain loss in metal silos, as reported by farmers was temperature changes which led to dampness of stored grain. According to Chigoverah and Mvumi (2016), an increase in temperature can cause metal silos to become damp on their interior walls and then transfer this moisture to the material that they store.

Table 9: Farmers' percentage responses on causes of grain loss in 2016/2017

Storage Technique	Percentage responses for reasons for loss (%)						
	n	Rodents	Insects	Damp	Theft	Improper Storage	No loss
Traditional granary	5	20	40	0	0	20	20
Metal silo	5	0	10	50	0	0	40
Polypropylene bags	112	14	65	2	1.7	0	16
PICS	14	29	15	0	0	0	57

4.3.6 Maize storage loss costs

The average price per kilogram of maize that farmers received per storage technique from maize grain sales after a given storage period was used to cost the loss. Average cost of the maize grain lost ranged from 250 Tshs to 374 Tshs for maize stored in traditional storage and polypropylene bags respectively as shown in Table 10. Storage loss cost was highest for polypropylene bags than the costs of all other storage techniques and the least for grain stored with traditional granary.

Table 10: Average maize loss costs (Tshs) per household for each storage technique

Type of Storage	n	Minimum	Maximum	Mean	Median	Std. Deviation
Traditional granary	4	250	250	250	250	00
Metal silo	3	250	417	302	330	62
Polypropylene bags	83	200	750	374	315	95
PICS	9	250	375	317	360	63

4.3.7 Net benefits (Tshs/kg) of maize storage techniques for given time duration

Table 11 presents the net benefit of maize storage in three different periods of time that is, below three months, four to six months and above six months for all techniques.

According to results presented in Table 11, net benefit of grain storage increased for farmers storing maize longer using traditional granary, however it decreased to negative for farmers storing maize for more than six months using polypropylene bags. This indicates that storing maize for more than 6 months in polypropylene bags is a loss and it might have been attributed to increased cost of grain management during storage. Net benefit also decreased when grain was stored for more than 6 months in PICS bags. More return was obtained from selling stored maize within four to six months of storage in this technique. Farmers who stored maize in metal silo for sell stored for more than 6 months and had the highest net benefits. According to Kimenju *et al.* (2010), storage in metal silo for more than 6 months recorded the highest gain compared to the control polypropylene bags and super bags which incurs storage loss per month.

Table 11: Net benefits (Tshs/kg) of maize storage techniques for given time duration

Storage techniques												
	Traditional granary			**Polypropylene Bags**			**PICS**			**Metal Silo**		
Months	≤3	4-6	>6	≤3	4-6	>6	≤3	4-6	>6	≤3	4-6	>6
Average grain stored/1000kgs	-	0.24	0.82	0.72	0.663	0.269	-	0.22	0.995	-	-	3.882
Price Tshs/kg	-	263	285	338	448	348	-	500	579	-	-	440
Loss cost Tshs/kg	-	25	55	34	32	76	-	33	31	-	-	34
Benefit Tshs/kg	-	500	430	352	405	413	-	550	462	-	-	1669
Total cost Tshs/kg	-	442	352	444	462	544	-	388	364	-	-	952.3
Net Benefit	-	58	78	92	57	-131	-	162	98	-	-	716.7

4.3.8 Economic viability of maize storage techniques

To establish the economic advantage of storage, discounted measures of project worthiness of NPV and BCR were calculated for storage techniques for periods after harvest where there was no storage and after a given period of grain storage. Storage bags, specifically traditional polypropylene bags were used for stocking of maize from farm to market for sale after harvest. Feasibility analysis on storage bags at 15% interest rate of selling maize after harvest without putting it in stores was computed and presented as shown in Table 12.

Farmers stored maize for sale in both traditional and modern hermetic storage structures. Average storage period differed from one technique to the other as it was shown in Table 6. Prices received by farmers after a given period of storage varied independently. This might have been attributed to farmer's ability to negotiate for higher prices and the amount of time a farmer was able to hold stored grain. Average benefit per kilogram ranged from 565 Tshs to 1669 Tshs for maize stored in the traditional granary and the hermetic metal silos respectively as shown in Table 12.

Table 12: Economic viability (Tshs) of improved storage techniques versus no storage

Average costs (TShs)/kg		Polypropylene bags		After Storage	
	Traditional granary	No Storage	After Storage	PICS	Metal silo
Investment	42.67	72.77	57.77	69.52	782.86
Depreciation	5	-	14.35	12	19
Labour	20	30.93	23.99	25	80
Repair &Maintenance	10	-	32	39	40.5
Insecticides	-	-	13.4	-	-
Storage loss	62	-	95.04	40	30
Total Costs	139.69	103.2	236.5	185.52	952.36
Discounted Costs	116.4	1403.85	1293	2856.0	1972.21
Benefits(Tshs/kg)	565.67	342.3	596.5	597.52	1669
Discounted Benefits	1852.8	4464	4154	5446.7	3628.01
BCR	2.56	3.18	3.21	1.9	1.8
NPV (Tshs)	2031	2422	3620	4202	6653

Note: The discount factor used was 15%, which is based on the bank rate for short term loan advances and all costs and benefits were measured in Tanzanian Shillings

From Table 12, it is feasible to use traditional storage bags for maize after harvest (no storage). The NPV is positive and the benefit cost ratio is greater than one indicating that the discounted benefits of not storing maize outweighs costs involved however, storing maize in polypropylene bags for a given period is more profitable than the no storage option. The NPV of polypropylene bags used for storage is also positive and greater than that of no storage option. The BCR is greater than one, also indicating feasibility of using polypropylene bags. Table 12 also shows comparison of the BCR and NPV of the four techniques after a given period of storage. From the BCR results, all storage techniques used were feasible with positive BCR.

Considering the net present values of storage techniques, polypropylene bags, metal silos, PICS bags and traditional granary were all feasible with positive values of 3620 Tshs, 6 653 Tshs, 4202 Tshs and 2031 respectively. Comparing all storage techniques, it can be concluded that metal silo was the most feasible investment with the highest positive net present value followed by PICS bags. Traditional techniques had the least positive NPVs. This might have been attributed to the ability of hermetic storage techniques to store grain at longer periods while maintaining its quality. This advantage over traditional storage techniques enabled farmers to sell grain when it was scarce thus fetching a higher price per kilogram of maize sold. Traditional stores are also associated with high losses as it was shown in Figure 3 and Table 12. A similar study by Mbwambo *et al.* (2016) also established that hermetic bags (PICS) were more viable than traditional polypropylene bags. The stream of discounted cash flow was as shown in appendix 2.

4.3.8 Sensitivity analysis

Results in Table 12 were subjected to different trial situations to establish what would happen given a certain percent reduction in the price level and a certain percent increment in the cost of storage structure and storage costs and vice versa. For this study, first a 20% cost increase and 30% price reduction then a 20% cost reduction and 30% price increase was assumed. A similar study by Nduku *et al.* (2013) performed a sensitivity analysis on ten storage techniques at ten percent cost increment and 30%, 40% and 50% price reduction. Sensitivity analysis at 15% interest rate on the NPV and BCR yielded the results shown in Table 13.

Table 13: Sensitivity analysis of maize storage techniques on financial indicators

	20% Cost Increase 30% Price Reduction		20% Cost Reduction 30% Price Increase	
Storage Technique	**BCR**	**NPV**	**BCR**	**NPV**
Traditional granary	3.25	5880	3.41	2911
Polypropylene bags	2.24	1320	3.16	5751
Metal silos	-3.42	-677	2.52	12877
PICS	4.93	1949	1.84	6456

From the results, if a 20% increment in cost and 30% price reduction occur, all storage techniques except the metal silo will remain viable investments with positive NPVs. For traditional granary, either of the situations will make investment more profitable than status quo. Table 13 also shows that NPV values for PICS and polypropylene bags are less than those presented in Table 12 for first option and more for the second option. This implies that a 20% increase in cost and 30% reduction in prices will make investing in either of the techniques less profitable compared to a situation where such changes have not occurred. Conversely, a 20% cost reduction and 30% price increase will make the investments more profitable. For metal silo, a 20% increase in cost and 30% reduction in price will makes investment in the technique not feasible as shown by a negative NPV. However, a 20% reduction on costs and 30% increase in price will make metal silos the most profitable investment than other techniques. BCRs for all techniques except the metal silo were also greater than one, indicating feasibility of all investments even when percentage changes in costs and price occur. The stream of discounted net cash flow for percentage changes in price and costs was as shown in Appendix 3.

4.4 Farmers' Perception on the Effectiveness of Grain Storage Techniques

Farmers rated storage techniques as either extremely effective (EE), effective (E), Undecided (U), ineffective (I) or extremely ineffective (EI) for each of the five given attributes on the effectiveness of the techniques. For the analysis, extremely effective and effective responses were taken as "effective" while extremely ineffective and ineffective responses were taken as "ineffective". Results from Table 14 show that, 60% of the farmers using traditional granary rated it as effective in reduction of household pest infestation and incidents of grain theft. However, more than half of farmers (60%) reported traditional granaries to be ineffective in prevention of grain exposure to physical damage and maintenance of good quality of grain during storage.

Table 14: Farmers' perception on the effectiveness of storage techniques

Effectiveness of storage techniques in…..	Storage Technique	Percentage Response (%)		
		Ineffective	Undecided	Effective
Reduction of household pest infestation?	Traditional granary	40	0	60
	Polypropylene bags	49	21	30
	PICS	0	5	95
	Metal silo	0	0	95
Maintain good grain quality during storage?	Traditional granary	60	20	20
	Polypropylene bags	56	20	24
	PICS	0	11	89
	Metal silo	0	25	75
Prevention of grain physical damage?	Traditional granary	60	20	20
	Polypropylene bags	55	20	25
	PICS	0	0	98
	Metal silo	0	0	100
Store grain longer than other techniques.	Traditional granary	40	20	4
	Polypropylene bags	40	28	32
	PICS	0	0	95
	Metal silo	0	0	100
Reducing incidents of grain theft.	Traditional granary	20	20	60
	Polypropylene bags	31	26	43
	PICS	0	0	95
	Metal silo	0	0	100

In the case of polypropylene bags, most farmers rated the technique as ineffective in maintenance of good quality of grain during storage (56%) and prevention of grain exposure to physical damage (58%). Less than half of farmers perceived polypropylene bags as effective in reduction of household pests infestation (30%), longer storage period than other storage techniques (32%) and reduction of incidence of grain theft (42%). Despite the negative perception that farmers had over polypropylene bags, it was the most used technique in the area. A conceivable explanation to this could be polypropylene bags are associated low investment and maintenance costs and ease of availability of the bags in the study villages.

Table 14 also summarizes farmers' responses on the effectiveness of hermetic storage techniques basing on their perceptions. Most of the hermetic storage technique users rated PICS and metal silos as effective storage techniques in all the categories. None of the farmers had a negative perception on PICS bags or metal silos. These results conform to similar studies by Mbwambo *et al.* (2016) and Adebayo *et al.* (2017).

After obtaining the perceptions for each category of storage techniques, a chi-square test was done to test the hypothesis that there is no significant difference in farmers' perception on the effectiveness of storage techniques. Results on the chi-square test in Table 15 only revealed significant differences in perception with respect to reduction of household pest infestation and maintenance of good quality of grain during storage period at ($P<0.01$) and ($P<0.05$) respectively. This shows that, farmers perceived traditional and hermetic storage techniques to have the same effectiveness in prevention of grain damage through temperature changes, store grain for a long period and reduction of incidents of theft.

Table 15: A Chi-square test on difference in farmers' perception on storage techniques

	Perception by storage techniques				
Effectiveness of techniques in…	**Traditional granary**	**Metal silo**	**PICS**	**Polypropylene bags**	**χ^2 test p value**
	% of respondents (n)				
Reduce pest infestation?	60(3)	95(5)	95(18)	30(38)	0.00***
Maintain grain quality	20(1)	75(4)	89(17)	24(27)	0.03**
Prevent grain damage	20(1)	100(5)	98(19)	20(22)	0.25
Store grain for longer period	40(2)	100(5)	95(18)	32(36)	0.16
Reduce grain theft.	43(2)	100(5)	95(18)	43(48)	0.42

Values are presented as a percentage of the response followed by number of respondents in brackets.

4.4.1 Ranking of grain storage techniques according to preference of use

Farmers also ranked grain storage techniques used basing on their preference of use. Both traditional and modern hermetic techniques were ranked within and among the two categories in a scale of five where 1 represented the most preferred and 5 the least preferred. Most farmers using the traditional grain storage technique ranked polypropylene bags (95.7%) as their first preferred choice among the traditional techniques used in the study area. Traditional granary (Kihenge) was ranked the second (4.3%). This implies that, in terms of convenience of use, most farmers found polypropylene bags more appealing especially considering the initial investment costs, handling, maintenance and expected use of grain after storage where 55% of farmers perceived polypropylene bags as effective in maintenance of grain quality during the storage period. In case of hermetic storage techniques, PICS bags (67.8%) were ranked as more preferred to use than the metallic silos (32.1%). This perhaps is due to high costs involved in installing the metal silos.

Using a survey questionnaire, farmers who were either familiar to or had used both, traditional and modern hermetic storage techniques ranked all the techniques in order of their preferences of use. Out of the four storage techniques, polypropylene bag was ranked the most preferred (39.1%) storage technique as shown in Table 16. This could be because most farmers were familiar with this technique as shown in previous tables where, polypropylene bags were the most used in 2016/2017 cropping season in both villages. Polypropylene bags were also the most affordable and easily available storage techniques in the area. The second most preferred storage technique was PICS bags (30.4%) followed by metallic silos (21.7%) and the least was the traditional granary (8.6%).

Table 16: Preference of use among traditional and hermetic grain storage techniques

Storage Technique	**Rank**	**Count**	**Percent**
Traditional granary	4	2	8.6
Polypropylene bags	1	99	39.1
PICS	2	7	30.4
Metal silos	3	5	21.7
Total		**113**	**100.0**

4.4.2 Principal Component Analysis on perception outcomes

The KMO measure of sampling adequacy was 0.785. The Bartlett's test of sphericity was significant ($\chi^2(10)$) = 294.399, $p < 0.01$) at 1%. Since both the tests met the minimum criteria, factor analysis was carried out. Out of five variables, principle component analysis extracted only one component which accounted for 63.554% of the variance. The perception was labeled maintenance of grain quality for PICS. This implies that households believed that using PICS bags would maintain the quality of grain during storage. A total of four items, which are storage technique's susceptibility to pest infestation, physical damage, theft and storage technique's ability to store grain for a longer time were eliminated because they did not contribute to simple structure factor and failed to meet a minimum criteria of primary factor loading of 0.5 or above.

4.5 Factors Determining the Choice of Grain Storage Techniques

Factors influencing farmers' choices of grain storage techniques were estimated to determine how smallholder farmers behave in making decision on the choice of grain storage techniques in postharvest grain management. The estimation of factors influencing the choice of grain storage techniques was conducted in order to test second hypothesis that there is no significant relationship between socio-economic and demographic characteristics of respondents and choice of grain storage techniques.

To determine significant factors that influence farmers in deciding which grain storage technique to use amongst the available options in the study areas, a multinomial logit model was adopted. The MNL model accommodated various storage techniques that were available in the study area to represent the categorical dependent variable. The MNL equation that was developed for this study accommodated four grain storage techniques which are traditional granary (Kihenge), polypropylene bags, PICS bags and metal silo.

Explanatory variables that were included in the MNL equation were; Age of household head (AGE), Sex of the household head (SEX), Education Level of the household head (EDU), Investment cost (INV), Storage benefit (BEN), perception on the effectiveness of technology (EFFPER), Farm size (FMS), Household size (HSIZE), Expected selling price after storage (EXP), Percent stored for sell (P_SELL), Percent stored for consumption (P_CONS) and Number of crops produced (CPROD).

4.5.1 Results from the multinomial logistic model

The MNL results summarize the demographic and socio-economic factors hypothesized to influence smallholder farmers' choices of grain storage techniques. It shows the likelihood of choosing to store in a given storage technique from a number of alternative grain storage techniques available in the study area. From the results, the identified multinomial logit model fits well the data as measured by Pseudo – R^2 (Cox and Snell = 35.1%, Nagelkerke = 58.5%, and McFadden = 47.2%). These values suggest a good predictive ability of the model implying that the explanatory variables included in the model explain well the variation in the dependent variable and goodness of fit. According to Louviere *et al*. (2000) as cited in Kadigi (2013), pseudo-R^2 sometimes though rarely, reaches values as high as those of R^2 in linear regression; therefore, the presented Pseudo – R^2 are still considered to have a good fit.

The log-likelihood ratio tests are used to indicate how best the model fits the information. Probability of the model (Chi square =51.824) was 0.008, less than the level of significance of 0.01 ($P<0.01$). The hypothesis that there is no significant relationship between socio-economic characteristics of respondents and choice of using grain storage techniques was rejected and the model, in favor of the alternative hypothesis concludes that socio- economic and demographic characteristics do influence farmers' choices of grain storage techniques. This also implies that the model can be used to explain the variation in preferences for smallholder farmers in the sample on the selected grain storage techniques. Metal silo storage technique was randomly selected as the reference category.

Table 17 summarizes variables influencing farmers' choices of grain storage techniques. Out of the 12 predictor variables used, 7 variables were significant, at least one in each category. Five out of the seven significant cases, had signs of the estimated coefficients that are consistent with the a *priori* expectations.

Table 17: Estimated results of the Multinomial Logistic Regression model

Variables	Traditional granary		Polypropylene bags		PICS	
	Coeff (β)	Significance	Coeff (β)	Significance	Coeff (β)	Significance
Intercept	4.698	0.367	5.236	0.081	0.111	0.971
AGE	-0.064	0.09*	0.029	0.549	0.059	0.242
HSIZE	0.069	0.810	0.055	0.807	0.059	0.800
FMS	-0.134	0.728	-0.229	0.391	-0.226	0.430
EXP	0.022	0.034**	-0.007	0.004***	0.000	0.953
INV	0.000	0.261	0.005	0.051	0.000	0.068*
BEN	0.003	0.655	0.023	0.389	0.033	0.516
EFFPER	0.056	0.755	-0.321	0.303	0.014	0.051*
CPROD	-0.752	0.503	0.345	0.081*	-0.160	0.808
P_SELL	-0.016	0.747	-0.048	0.005***	-0.052	0.06*
P_CONS	0.000	0.938	-0.002	0.141	-0.008	0.109
SEX(0=Male)	0.575	0.738	0.111	0.928	0.080	0.951
EDU(0=Non-Educated)	1.219	0.452	0.894	0.032**	0.172	0.892

Note: ***, ** and * Significant at 0.01, 0.05 and 0.1 levels respectively.
Chi-Square=51.824, Prob>chi2=0.008; Number of observations= 120

Significant variables were age of the household head, education of the household head, expected price after storage, investment costs, farmers' perception, percent of produce stored for sell and number of crops cultivated by a household.

Coefficients of the multinomial regression are used to show the direction of effect of the independent variables on the dependent variables. Results in Table 17 shows that age of household head influences choice of traditional granary negatively, on the contrary to how it was expected. The coefficient of variable age for traditional granary was negative and significant implying that, with age a farmer will tend to be sensitive with loss hence they are less likely to choose traditional granary (with potentially high loss) over metal silo. According to Maonga *et al.* (2013), the probability of adopting hermetic storage techniques increases with the increase in farmer's age however it stops after a certain age as farmers become more risk averse and prone to resist changes in the status quo in farming activities.

The coefficients of the variable expected price after storage are negative and significant at 5% ($P<0.05$) and 10% ($P<0.1$) for traditional granary and polypropylene bags respectively. This means that farmers are less likely to choose polypropylene bags and the traditional granary to store grain for sell over the metal silos when price of grain is expected to increase after storage. This might be attributed to the fact that unlike with the metal silo, farmers do not have confidence in these techniques that high price could be realized due to potential loss in quantity and quality associated with them. Metal silos store grain for longer period while maintaining good grain quality. However, these results differ from findings by Gitonga *et al.* (2015) where farmers preferred storing grain for consumption with hermetic storage techniques while they sold grain stored with chemicals in traditional bags such as polypropylene bags.

Table 17 also shows that coefficients for investment costs were positive and significant at 10% ($P<0.1$) for the polypropylene bags and PICS bags. This implies that as investment costs increases, farmers become more likely to choose to store grain in polypropylene bags and PICS bags than in metal silo. The sign was not as expected and a conceivable explanation to this is that most of the small holder farmers cannot afford high costs involved in installation of metallic silos.

Farmer's perception on the effectiveness of grain storage techniques was positive and significant at 10% ($P<0.1$) for the choice of polypropylene bags over the metal silo. The results conform to the expected sign. The principal component analysis indicated that most farmers believed PICS to be good technique in terms of quality maintenance thus they choose the technique over metal silo. Percentage of quantity stored for sell was negative and significant at 1% ($P<0.01$) and 10% ($P<0.1$) for polypropylene bags and PICS respectively. This result differ from what was expected and it implies that with an increase in percent of quantity stored for sell of the total quantity produced, farmers are more likely to choose the metal silos than polypropylene and PICS bags. This might be attributed to high prices that farmers expect to sell their grain after a relatively longer period of grain storage. It was shown in Table 14 that 100% of farmers perceived metal silos to store grain at a longer period compared to other storage techniques while 75% perceived metallic silos to maintain a good quality of grain after storage.

As it was expected, the coefficient of number of crops cultivated per household is positive and significant at 1% ($P<0.01$) for polypropylene bags category implying that with more crops a farmer may need more bags to store individual crops separately. Polypropylene bags were the cheapest storage techniques compared to other storage techniques.

Education of household head also had a positive and significant effect at 5% ($P<0.05$) on farmers' choice of polypropylene bags over metal silos. Farmers who are non-educated are more likely to choose polypropylene bags over metal silos compared to educated farmers. According to Maonga *et al*. (2013), education has a positive influence on the adoption of improved grain storage techniques due to the fact that educated farmers stand a better chance to acquire new information and appreciate the importance of modern technologies through improved understanding.

The estimation of odds ratio was also done relative to the baseline, that is, the coefficient of probabilities of the respondents using traditional granary, polypropylene bags and PICS bags were estimated with respect to metal silo storage technique. Positive coefficient implies that the probability of a respondent falling in the numerator category (traditional granary, polypropylene bags, and PICS bags) is greater than probability of falling in the reference category (metal silos). Table 18 presents the odds ratio of only significant variables which were discussed in the presentation.

From Table 17, 7 variables are significant, 5 of which are continuous and 2 as a categorical variable. Continuous variables are age, investment costs, expected price after storage, percent of grain stored for sell, and number of crops cultivated per household while the categorical variable is the education level of household head and farmers' perception on effectiveness of storage techniques. From the traditional granary category, age of the household head affects choice negatively thus the odds ratio can be interpreted as; A year increase of age, multiplies the odds (probability) of selecting metal silos rather than traditional granary by 1.066. The coefficient of the variable expected price after storage was also negative implying that a unit increase in the expected price of grain after storage multiplies the odds (probability) of selecting metal silos rather than traditional granary by 0.978.

Table 18: Estimated odds ratio of the Multinomial Logistic Regression model

	Traditional Granary		**Polypropylene Bags**		**PICS**	
Variables	**E(β)**	**P value**	**E(β)**	**P value**	**E(β)**	**P value**
AGE	1.066*	0.09	1.030	0.540	1.061	0.242
EXP	0.978**	0.034	0.993***	0.004	0.953	1.000
INV	1.000	0.261	1.000*	0.051	1.000*	0.068
EFFPER	0.872	0.755	1.076	0.303	1.057*	0.051
PQSOLD	0.984	0.747	0.953***	0.005	0.950*	0.066
CPROD	0.471	0.503	0.985*	0.081	0.852	0.808
EDU(0=non Educated)	3.103	0.452	2.575**	0.032	1.258	0.892

It is also observed from Table 17 that the coefficients of expected price after storage (EXP), investment cost (INV), percentage of quantity sold (PQSOLD), number of crops produced (CPROD) and education level of household head (EDU) were significant in the choice of polypropylene bags. Coefficients for expected price after storage and percent of crop sold were negative implying that, holding other factors constant, a unit increase in either of the variables will multiply the odds of using metal silos rather than polypropylene bags by 0.993 and 0.953 respectively. Also, a percentage increase in the crop stored for sell will multiply the odds of using polypropylene bags rather than metal silos by 0.953, holding other factors constant. A unit increase in the number of crops produced will increase the odds (probability) of using polypropylene bags rather than metal silos by 0.985. Holding other factors constant, the odds (probability) of a non-educated household head, selecting polypropylene bags rather than metal silos is 2.575 times higher than an educated household head.

In the case of PICS bags storage technique, the coefficients of investment cost (INV), percent of crop stored for sell and perception of storage technique on reduction of stored crop loss are positively significant. This implies, holding other factors constant, a unit increase in either investment cost or percent of crop stored for sell will multiply the odds (probability) of using PICS rather than metal silos by 1.000 and 0.950 respectively. Also, as farmers increase their belief on PICS to be effective in reduction of crop loss through prevention of household pest infestation, the probability of choosing PICS bags increases by 1.057.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Increasing agricultural production and productivity has been the main focus for most of development and poverty alleviation programs. Farmers have been encouraged to use improved seeds, adopt improved farm technologies and use of chemical fertilizers. However, these programs ignore post-harvest grain management which has proven to be a constraining factor towards successful agricultural production in developing country. This study aimed to analyze the economics of grain storage techniques utilized in Kilosa district in Tanzania so that informed policy may promote storage techniques that increase farmers' income and reduce stored crop losses. Specifically, the study aimed at computing costs and benefits associated with use of traditional and modern hermetic techniques, analyze farmers perception on the effectiveness of storage techniques in crop loss reduction and identifying determinants of farmers' storage choice decisions.

5.2 Conclusions

The study concluded that among all storage techniques, polypropylene bags were the most used for storage of cereals and legumes. Other storage techniques used include traditional granary (Kihenge), and hermetic techniques which are PICS bags and the metal silos. Most farmers who used hermetic storage techniques also used traditional storage polypropylene bags.

The study, through establishment of net benefits of storage techniques for farmers who store below three months, between four to six months and above six months has identified that storing grain in polypropylene bags for a long period is a loss as these are associated with the highest crop losses, (19% of stored crop) and high crop management costs during storage. However, net benefits from storing maize in modern hermetic techniques increased when grain was stored for 4 to 6 months and were highest for grain stored for more than 6 months in metal silos.

Results through measures of project worthiness of NPV and BCR have also shown that traditional granary, metal silos, polypropylene bags and PICS are all feasible maize storage techniques with positive NPV and BCR when discounted for 15 years at 15% interest rate. The metal silo had the largest NPV, showing that metal silo was the most profitable compared to others. A sensitivity analysis performed on the techniques assuming first a 20% increase in cost and 30% reduction in price have shown that all storage techniques except the metal silo would remain feasible. The second assumption, which was 20% cost decrease and 30% price increase showed that all four techniques would still remain feasible while the metal silo being the most profitable technique to use. On comparing the NPV of traditional polypropylene bags when used before storage to stock and sell maize and when used to store maize and sell later, the study concluded that it is more profitable to store maize and sell later in the first 5 months than to sell maize after harvest.

With regard to the second objective on perceptions, more than half of farmers using traditional storage techniques perceived traditional granary as more effective technique in reduction of crop loss than polypropylene bags. Farmers also perceived traditional storage techniques to be ineffective in maintaining good quality of grain during storage and prevention of grain from exposure to physical damage through temperature changes. Unlike traditional stores, 98% of farmers perceived all hermetic storage techniques to be effective in crop loss reduction and stored grain for a longer time while maintaining its quality. However, these were not commonly used, especially the metal silos. Due to low income levels, high purchase price of the metallic silos proved to be the most important limiting factor to the silo technology use. Farmers also ranked polypropylene bags as the most preferred storage technique followed by hermetic techniques. This was due to its ease in accessibility and affordability. Traditional granary was the least preferred technique.

The findings related to the third specific objective show that socio-economic and demographic factors have a significant influence on farmers' choice of grain storage techniques. Factors such as expected price after storage had a significant effect on the choice of metal silos over traditional granary at 5% ($P<0.05$) while Age of household age had a significant effect on the choice of traditional granary over metal silo at 10% ($P<0.1$). Investment costs, number of crops cultivated and education status of household head significantly affected the choice of polypropylene bags over metal silo at 10% ($P<0.1$), 1% ($P<0.01$) and 5% ($P<0.05$) respectively. Expected price after storage and percentage of crops stored for sell significantly affected the choice of metal silos over polypropylene bags at 10% ($P<0.1$) and 1% ($P<0.01$) respectively. The choice of PICS bags over metal silos was significantly affected by investment costs, percent of crop stored for sell and farmers' perception on the effectiveness of the technique at 10% ($P<0.1$).

5.3 Recommendations

From the findings made in the study, the following recommendations are made towards improving storage environment in Tanzania and improving well-being of small holder farmers.

5.3.1 Recommendations for policy implication

The study has shown that storage of grain will not always increase household income especially when traditional polypropylene bags are used. This is an important finding that should be included in post-harvest management training programs. Since hermetic storage techniques are not only the most profitable but also durable and most effective in reduction of post-harvest losses, farmers should be encouraged to use through financial support such as provisioning of credit to purchase the techniques and subsidization of the techniques so as to make them affordable to farmers. Farmers can also form groups and purchase metal silos as a group to store maize therefore creating community owned structures for food reserves and income generation through selling of stored grain.

Also, since education of household head had a significant effect on the choice of hermetic storage techniques, the government and private sectors should invest in provision of education to farmers on the hermetic grain storage techniques so as to influence them to use the techniques as these do not only increase household income but also involve no use of storage chemicals, maintain good quality of grain after storage and very effective in storing grain for longer periods. Provision of post-harvest grain management education should also include information on costs and benefits accrued to various storage techniques; farmers should understand how much loss is associated with improper storage management and how these losses can be minimized through the use of improved storage techniques. This will enable them make informed decisions on investing in storage techniques.

5.3.2 Areas for Further Research

The storage techniques considered in this study were traditional granary, polypropylene bags, PICS and metal silos. However, there are other grain storage techniques that are most likely important for grain storage and were not considered in this study. These include improved traditional techniques plastic drums, hermetic drums and plastic silos. Future studies may include other storage techniques that were not considered in this study.

The study also observed socio-economic factors that are quantity stored, investment cost, percentage of crops stored and expected price after storage. Other factors such as cultural and societal factors like norms, beliefs and values that were not considered in this study but are likely to influence farmers’ choice of storage techniques. Further studies on this area should consider these factors and incorporate them in the study.

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APPENDICES

Appendix 1: Farmers Questionnaire

Title: Economics of Grain Storage Techniques for Smallholder Farmers in Kilosa District, Tanzania.

1.0 Interview Information

A: INTERVIEWER'S NAME	
B: NAME OF RESPONDENT	
C: NAME OF HEAD OF HOUSEHOLD.	
D: NAMES OF SPOUSE	
E: NAMES OF FIRST TWO CHILDREN	
F: AGE OF HH HEAD (Years)	
G:SEX OF HH HEAD (1=Female; 2=Male)	
H: HOUSEHOLD ID	
I: VILLAGE NAME	
J: HAMLET NAME	

2.0 Knowledge on Hermetic Storage Structures and Adoption

2.1If aware of newly introduced airtight bags (Pics) and airtight containers (silos).

1. Yes 2. No [ ]

2.2 If yes, which of the storage structures have you adopted?

1. Pics 2. Metal Silos 3. Plastic Drums 4.Plastic tins 5. Metal drums 6.Metal Tins

7. Other [ ]

2.3 When did you start using the following storage structures?

S/N	Storage Structures	Time began to use (MM/YR)
1	Air tight bags	
2	Metal Silos	
3	Plastic Drums	
4	Plastic Tins	
5	Metal Drums	
6	Metal Tins	
7	Others (Specify)	

2.4 Which traditional storage structures have you been using?

i…………………………….. iv……………………..

ii……………………………. v………………………

iii……………………………

2.5 Sources of the first information about hermetic stores.

1. Family 2.Friends 3.Neighbours 4.Extension 5.Experience 6.Project (Mention it)…………………………… 7.Others (Specify)………………………… [ ]

2.6 Please complete the table below

Crop*	**Date of last harvest**	**Total stored last harvest**		**Method of Storage****	**Storage purpose*****	**Amount of this harvest in store now**	**When store depleted**	**Loss in store? 1 = Yes, 2 = No**	**Estimated quantity lost in store?**		**Reason for loss********
		Unit	Amount			Quantity	Approx. Date		Unit	Amount	

*Crops: 1 = Maize, 2= Beans, 3= Pigeon Peas 4. Cowpeas 5.Others (Specify);

**Method of storage: 1=Airtight bags (Pics), 2= Metal Silos 3= Plastic Drums 4=Plastic tins 5=Metal drums 6=Metal Tins, 7=Polythene bags, 8=Sisal Bags 9= Chanja 10= Kihenge 11= Traditional Granaries 12=Others (specify)__________

***Main purpose of storage: 1=Food for household, 2=To sell for higher price, 3=Seed for planting, 4=Other (specify) _____________

****Reasons for loss: 1 = Rodents, 2 = Insects, 3 = Damp/rot, 4 = Theft, 5 = Others (Specify) _________________

3.0 Attitudes & Perception on Traditional and Hermetic Storage Techniques

3.1 Which of the storage structures are effective for crop loss reduction?

1. Traditional Storage Structures 2. Modern hermetic storage structures [ ]

3.2 Why do you perceive that?

a. …………………………………..

b. …………………………………..

c. …………………………………...

3.3 If chose 2 in (3.1) did you respond by adopting either of the modern hermetic structures?

1. Yes 2. No [ ] If yes, go to (3.6)

3.4 If you disagree (for those who say no in 3.3) go to 3.5.

3.5 Please tick an option from scale to show how you perceive traditional structures to be effective or not effective with each of the following statements.(EE=extremely effective, E=Effective, U=Undecided, I=Ineffective, EI=Extremely ineffective)

How effective are traditional storage structures in ……….?	Traditional stores	EE	E	U	I	EI
Reduction of household pest infestation?	a.Polythene bags					
	b.Sisal Bags					
	c. Vihenge					
	d.Chanja					
	e.Others(specify)					
Maintaining good quality of grain within six months of storage?	a.Polythene bags					
	b.Sisal Bags					
	c.Vihenge					
	d Chanja					
	e. Others (Specify)					
Prevention of grain exposure to physical damage?	a.Polythene bags					
	b.Sisal Bags					
	c. Vihenge					
	d. Chanja					
	e. Others (Specify)					
Traditional stores with insecticides can store grain at a longer period than modern stores?	a.Polythene bags					
	b.Sisal Bags					
	c. Vihenge					
	d. Chanja					
	e. Others (Specify)					
Traditional stores in not being susceptible to grain theft?	a.Polythene bags					
	b.Sisal Bags					
	c. Vihenge					
	d. Chanja					
	e. Others (Specify)					

3.6 Please tick an option from scale to show how you perceive modern hermetic storage structures to be effective or not effective with each of the following statements. (EE=extremely effective, E=Effective, U=Undecided, I=Ineffective, EI=Extremely ineffective)

How effective are modern storage structures……….?	Modern storage Structures	EE	E	U	I	EI
Reduction of household pest infestation?	a.Airtight Bags (Pics)					
	b. Metal Silos					
	c.Metal Tins					
	d. Metal Drums					
	e.Plastic Drums					
	f. Plastic Tins					
	g.Others (Specify)					
Maintaining good quality of grain within six months of storage?	a.Airtight Bags (Pics)					
	b. Metal Silos					
	c.Metal Tins					
	d. Metal Drums					
	e.Plastic Drums					
	f. Plastic Tins					
	g.Others (Specify)					
Prevention of grain exposure to physical damage?	a.Airtight Bags (Pics)					
	b. Metal Silos					
	c.Metal Tins					
	d. Metal Drums					

	e.Plastic Drums					
	f. Plastic Tins					
	g.Others (Specify)					
Modern stores with insecticides can store grain at a longer period than traditional stores?	a.Airtight Bags (Pics)					
	b. Metal Silos					
	c.Metal Tins					
	d. Metal Drums					
	e.Plastic Drums					
	f. Plastic Tins					
	g.Others (Specify)					
Modern stores in not being susceptible to grain theft?	a.Airtight Bags (Pics)					
	b. Metal Silos					
	c.Metal Tins					
	d.Metal Drums					
	e.Plastic Drums					
	f. Plastic Tins					
	g.Others (Specify)					

3.7 Please rank the following storage structures according to their importance of use within and among the two categories. (Rank in a scale of 1 to 14)

Hermetic Storage Structures	**Tick the type of Storage Used**	**Rank in order of Importance (1-5)**	**Rank in Order of their importance between the two categories (1-10)**
Pics			
Metal Silos			
Metal Drums			
Plastc Drums			
Plastic Tins			
Metal Tins			
Others (Specify)			
Traditional Storage Structures		Rank in Order of Importance (1-5)	
Polythene Bags			
Sisal Bags			
Traditional Granaries			
Chanja			
Vihenje			
Others(Specify)			

4.0 Components of Costs and Returns

4.1 Please complete the table below on the quantity of grain stored and price of grain sold in the previous season (2017/2018).

Crop Cultivated	Month harvested	Quantity stored for consumption	Quantity stored for sell	Price of grain at harvest	Price of grain after storage

4.2 Do you have access to credit services in your area?

1. Yes 2. No [ ]

4.3 If YES, have you ever accessed loans for agricultural activities?

1. Yes 2. No [ ]

4.4 What are the costs associated with the use of the modern farm storage structures per year? (Tshs/ 100kg bag or container)

4.4.1 Please complete the table below indicating the quantities of storage structures used and their costs for calculation of fixed costs (Q= Quantity of Bags Containers, C= Cost of each)

Types of Costs			**Modern Storage Techniques**						**Traditional Storage Techniques**				
			PICS	Metal Silos	Metal Drum	Metal Tin	Plastic Drum	Plastic Tin	PP bag	Sisal Bags	Chanja	Vihenge	Plastic Container
FIXED COST	1.Storage Capacity	**Q**											
		C											
	2.Capital Costs	**Q**											
		C											
	3.Useful Life	**Q**											
		C											

B. Operational Costs

4.4.2. Please complete the operational costs for modern storage structures used below

(**FL**=Family labor; **HL**=Household labor in an 8 hours working day; **P**=Number of people; **D**=Number of Days; **H**=Numbers of hours spent)

Type of Costs	Categories	PICS			Metal Silos			Metal Drums			Metal Tins			Plastic Tin			Plastic Drums		
		FL	HL	Cost	FL	HL	Cost	FL	HL	Cost	FL	HL	Cost	FL	HL	Cost	FL	HL	Cost
		FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8		
Labour Costs	1.Construction																		
	2.Packing																		
	3.Staking																		
	4.Inspecting																		
	5.Dusting																		
	6.Repair																		
Insectcide																			
Percentage loss																			

4.4.3. Please complete the operational costs for traditional storage structures used below (FL=Family labor; HL=Household labor in an 8 hours working day; P=Number of people; D=Number of Days ;H=Numbers of hours spent)

Type of Costs	**Categories**	**Polythene Bags**			**Sisal Bags**			**Chanja**			**Vihenge**			**Plastic Containers**		
		FL	**HL**	**Cost**	**FL**	**HL**	**Cost**	**FL**	**HL**	**Cost**	**FL**	**HL**	**Costs**	**FL**	**HL**	**Cost**
		FL,HL=(P*D*H)/8			**FL,HL=(P*D*H)/8**			**FL,HL=(P*D*H)/8**			**FL,HL=(P*D*H)/8**			**FL,HL=(P*D*H)/8**		
Labour Costs	1.Construction															
	2.Packing															
	3.Staking															
	4.Inspecting															
	5.Dusting															
	6.Repair															
Insecticide																
Percentage loss																

THANK YOU FOR YOUR COOPERATION

Appendix 2: Calculation of NPV for each grain storage technique involved in the study

Net present value for traditional granary

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Net cash flow	-43	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Discount Factor	1	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.64	0.61	0.58	0.56	0.53	0.51	0.48
Discounted net cash flow	-43	190	182	172	164	156	150	142	136	128	122	116	112	106	102	96

NPV= Summation of net cash flow= 2031

Net present value for traditional polypropylene bags
Before maize storage

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Net cash flow	-58	239	239	239	239	239	239	239	239	239	239	239	239	239	239	239
Discount Factor	1	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.64	0.61	0.58	0.56	0.53	0.51	0.48
Discounted net cash flow	-58	227	217	206	196	186	179	170	163	153	146	139	134	127	122	115

NPV= Summation of net cash flow= 2422

After maize storage

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Net cash flow	-58	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
Discount Factor	1	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.64	0.61	0.58	0.56	0.53	0.51	0.48
Discounted net cash flow	-58	342	328	310	295	281	270	256	245	230	220	209	202	191	184	173

NPV= Summation of net cash flow= 3620

Net present value for Metal silos

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Net cash flow	-783	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717
Discount Factor	1	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.64	0.61	0.58	0.56	0.53	0.51	0.48
Discounted net cash flow	-783	681	652	617	588	559	538	509	488	459	437	416	402	380	366	344

NPV= Summation of net cash flow= 6653

Net present value for PICS bags

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Net cash flow	-70	412	412	412	412	412	412	412	412	412	412	412	412	412	412	412
Discount Factor	1	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.64	0.61	0.58	0.56	0.53	0.51	0.48
Discounted net cash flow	-70	391	375	354	338	321	309	293	280	264	251	239	231	218	210	198

NPV= Summation of net cash flow= 4202

Appendix 3: Sensitivity analysis

Net present value for traditional granary

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20% cost increase	Net cash flow	52	572	572	572	572	572	572	572	572	572	572	572	572	572	572	572
30% price reduction	Discounted net cash flow	-52	543	521	492	469	446	429	406	389	366	349	332	320	303	292	275
20% cost reduction	Net cash flow	35	284	284	284	284	284	284	284	284	284	284	284	284	284	284	284
30% price increase	Discounted net cash flow	-35	270	258	244	233	222	213	202	193	182	173	165	159	151	145	136

NPV_1=5880

NPV_2=2911

Net present value for polypropylene bags

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20% cost increase	Net cash flow	70	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
30% price reduction	Discounted net cash flow	-70	127	122	115	110	105	101	95	91	86	82	78	75	71	68	64
20% cost reduction	Net cash flow	45	559	559	559	559	559	559	559	559	559	559	559	559	559	559	559
30% price increase	Discounted net cash flow	-45	531	509	481	458	436	419	397	380	358	341	324	313	296	285	268

NPV_1=1320

NPV_2=5751

Net present value for Metal silos

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20% cost increase	Net cash flow	939	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
30% price reduction	Discounted net cash flow	-939	24	23	22	21	20	19	18	17	16	15	15	14	13	13	12
20% cost reduction 30% price increase	Net cash flow	626	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408	1408
	Discounted net cash flow	-626	1338	1281	1211	1155	1098	1056	1000	957	901	859	817	788	746	718	676

NPV_1= -677

NPV_2=12877

Net present value for PICS

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20% cost increase	Net cash flow	84	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196
30% price reduction	Discounted net cash flow	-84	186	178	169	161	153	147	139	133	125	120	114	110	104	100	94
20% cost reduction	Net cash flow	56	628	628	628	628	628	628	628	628	628	628	628	628	628	628	628
30% price increase	Discounted net cash flow	-56	597	571	540	515	490	471	446	427	402	383	364	352	333	320	301

NPV_1=1949

NPV2=6456