

**MAIZE STORE–TIME MARKETING MODEL FOR NORTHERN ZONE OF
TANZANIA**

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**A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of
Master's in Life Sciences of the Nelson Mandela African Institution of Science and
Technology**

Arusha, Tanzania

April, 2019

ABSTRACT

This study was carried out to create a marketing model that integrate maize store-time with five storage methods namely Perdue Improved Cowpeas Storage bags (PICS), Metal Drums, *Kihenge*, Polyethylene bags with insecticides and Polyethylene bags without insecticide. Trials were established following a randomized complete block design with four replications in Kilimanjaro, Arusha and Manyara regions, and treatments were monitored for weevil's infestation for six months consecutive. The results showed PICS bag was the most efficient storage method in minimizing insect damaged kernels as it only contributed to 1% of the insect damaged kernels, while other methods such as Metal drum, *Kihenge*, Polyethylene bag with insecticide and Polyethylene bag without insecticide resulted in 4%, 23 %, 29%, and 43% insect damaged kernels respectively. The correlation matrix showed similar results with coefficients of correlation of -0.378, -0.272, 0.045, 0.037 and 0.516 respectively. With regards to store-time PICS bag and Metal drum had the lowest number of insect damage throughout six-month store-time. Other methods such as Polyethylene bag with insecticide was able to keep the kernel insect free only for three months while Polyethylene bag without insecticide kept grains free of weevil infestation only for one month. The results also indicated that there was a significant relationship between marketing channels and income gained by the household with P -value = 0.04. Average store-time for the majority of the respondents was six months. This study recommends not more than seven month store-time for household income optimizations.

DECLARATION

I, **Jennifer Swai** do hereby declare to the Senate of the Nelson Mandela African Institute of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution

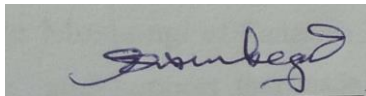


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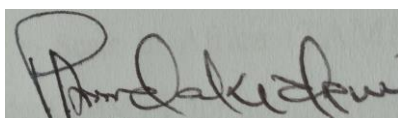
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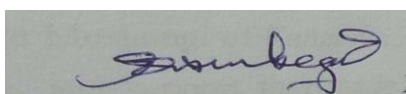
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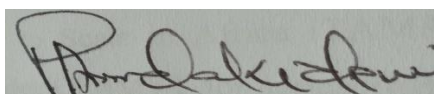
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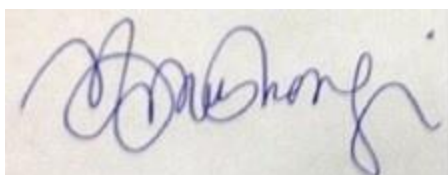
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ACKNOWLEDGMENT

First and foremost, I would like to thank my almighty God for his mercies and grace which gave me strength and courage to carry out my studies at the Nelson Mandela African Institution of Science and Technology. Next, are my parents and family for the motivation and encouragement they have always given me for all the endeavors I have pursued.

I would like to spread my sincere gratitude to my esteemed supervisors Prof. Patrick Aloyce Ndakidemi and Dr. Ernest Mbega of Nelson Mandela African Institution of Science and Technology as well as Dr. Arnold Angelo Mushongi of Tanzania Agricultural Research Institute – Ilonga, for their guidance, assistance, and support that made this study successful. These mentors were always willing to take time to answer my questions and challenge me to think critically through every step of the research to ensure successful accomplishment of this dissertation.

I spread out my inner gratitude to the African Development Bank for sponsoring my studies and the Taking Maize Agronomy to Scale in Africa (TAMASA) project funded by the Bill & Melinda Gates Foundation under CIMMYT for sponsoring part of the research work. Heartfelt appreciations are extended to the Extension Officers in Babati, Karatu, Hanang, Mbulu, Hai, Siha, Arumeru, Monduli and Moshi Rural Districts for their valuable support and cooperation.

Last but not least, I thank my colleagues in the Sustainable Agriculture Department for their moral and social support.

DEDICATION

I dedicate this piece of work to my beloved son and daughters Ebenezer Efraimu Malisa, Ellyn Efraimu Malisa, and Elizabeth Efraimu Malisa, and my parents Mr. and Mrs. Sawe Swai for taking care of my children in my absence throughout my studies. Their inspirations, encouragement, and prayers are highly appreciated.

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LIST OF ABBREVIATIONS

TAMASA	Taking Maize Agronomy to Scale in Africa
CIMMYT	International Maize and Wheat Improvement Center
VIF	Variance Inflation Factor
SSA	Sub-Saharan Africa
GDP	Gross Domestic Product
USD	United State Dollar
PICS	Perdue Improved Cowpeas Storage
FGD	Focused Group Discussions
AIC	Akaike Information Criteria
NM-AIST	Nelson Mandela Institution of Science and Technology

CHAPTER ONE

INTRODUCTION

1.1. Background Information

Maize (*Zea mays* L.) ranks next to wheat and rice in cereal crops, with a world production of about 10.14 billion MT (Suleiman and Rosentrater, 2015). The world's biggest producer of maize is the United States of America that produces about 30% of the global maize followed by China 21% and Brazil 7.9%. Africa contributes about 7% of the overall world maize production whereby, Eastern and Southern Africa contribute two-third of the total production (Verheye, 2010; Ranum *et al.*, 2014). Maize contributes to the per capita energy consumption and incomes in the developing countries considering it as a cash crop as well as a food crop. In Sub-Saharan Africa (SSA), maize is a staple food of about 1.2 billion people and it occupies about one-third of total cultivated land (Blackie, 1990).

Maize contributes about 20% of the Tanzania Gross Domestic Product (GDP) (National Agricultural Policy, 2013), over 30% of household income, 60% of dietary calories and 50% of protein intake (Suleiman and Rosentrater, 2015; Amani, 2004, URT –MAFC, 2013). The crop is produced by small scale farmers who occupy over 80% of the population and it is consumed by more or less the same portion of the people in Tanzania. The World Bank Report (2009) projected that the growing urbanization and high rates of poverty would bring up a limited dietary upgrading; thus market demand for food staples would grow steadily to USD 11.2 billion in 2015 and USD 16.7 billion in 2030. Considering the fact that, within Tanzania, maize can be grown throughout the year; during ‘Masika’ a Swahili description referring to long rains and ‘Vuli’, also Swahili describing short rains, (Verheye, 2010) such demand can be a marketing opportunity for Tanzania. About 41 % of maize is grown during the “Masika” season and 47% is grown during the “Vuli” season while the remaining ratio is grown under irrigation, thereby allowing constant production of maize around the year (WFP, 2010). Despite the favorable growing conditions and the contribution of maize, the average national yield has been stagnantly very low, averaging to about 1.4 t/ha under farmer's conditions (FAO, 2015). The Northern Zone of Tanzania i.e Arusha, Kilimanjaro, and Manyara regions, contributes about 10–15% of the total yield (Zorya and Mahdi, 2009).

The harvested maize is usually stored in a diversity of traditional methods and structures. Most of the methods or structures used by farmers are not improved enough to keep the

maize grain from storage insect pest infestation, as a little that is produced is lost due to not only insect pests as described but also due to poor post-harvest handling methods. Chomchalow (2003), Matthews (2006) and Kumar and Kalita (2017) estimated postharvest losses of maize grain ranging from 20–30% of the produced grain where storage insects account for up to 40% of the physical and nutritional value of grain degradations. This brings a big threat to the nation household food security and per capita income as well. Therefore, in order to secure the little production that is produced, there is an urgent need to develop a strategy that integrates storage structures/methods and their store–time so that the produced grains will be consumed at a time point that is the most profitable for the producer.

Emphatically, the national investments on increasing agricultural production and productivity should match reduced post-harvest losses (Proctor, 1994; Holst *et al.*, 2000). Economic principles, such as modeling prevailing storage structures in relation to store–time would significantly contribute to minimizing postharvest losses in Tanzania. Urgent strategies specifically, designing user-friendly, resilient and affordable postharvest losses interventions for maize growers is needed (Makinde *et al.*, 2001). Thamanga–Chitja *et al.* (2004) asserted that improved and low-cost storage technologies should be readily accessible to farmers to safely store and sustain the value of their produces. Following the same line of thinking, time of harvest, storage–time and storage structures need to be characterized and modeled along the different nodes of the maize value chain into a form that would provide maximum return to investments to smallholder farmers in Tanzanian.

In Northern Tanzania farmers rely store their maize on traditional storage facilities such as raised grass–thatched, mud–plastered hut on pillars or “Kihenge” Kiswahili for food and seed preservations (Rugumamu, 2003; Makalle, 2012). In these locations, farmers have limited access to improved storage techniques such as metal silos, hermetic bags, and warehouses facilities. Nevertheless, the traditional storage facilities hold a competitive advantage over the improved one because they are relatively simple and accessible with minimum investment cost. Studies on the promotion of improved storage structures (De Groote *et al.*, 2013; Teferra *et al.*, 2012; William *et al.*, 2017) have not researched on gaps from traditional storage methods at smallholder level. Thus, there is a need to characterize maize storage structures in order to identify strategies that can minimize losses in the country. Research-based agribusiness models along the different nodes of the maize value chain to find out maize postharvest problems are required. Furthermore, farmers need to be well

informed on the contributions of the store–time and storage structures in insect-damaged kernels as one of their decision supporting tools, for enhancing household food safety and security which is the main focus of this study.

1.2. Problem Statement and Justification

There exists a puzzle “sell low and buy high” in developing countries due to improper storage facilities (Stephens and Barrett, 2011; Park, 2006). This mystery supposes that farmers with little liquidity asset sell grain early at a low price during the harvest period, while they buy same grain later at a high postharvest price just four to six months later. Debts such as school and other social obligations are generally due in the immediate post-harvest period. Farmers must be able to meet their debts in the harvest season through credit or sufficient personal savings, rather than immediately grains sells so as to cover these obligations to improve their store-time for marketing purposes (Stephens and Barrett, 2011). Storing grains for future sale requires a producer to forego investing postharvest grain sales in other revenue-generating activities that may generate very high rates of return which could very well outpace returns from commodity storage (Lowenberg-Deboer *et al.*, 1994).

Numerous studies in the Sub-Saharan African countries reported that adoption of improved maize varieties contribute to a raising productivity, household income and food security (Katengeza *et al.*, 2012; Mason and Smale, 2013; Bezu *et al.*, 2014). On the contrary, Ricker and Jones (2015) report that higher yielding varieties are more susceptible to storage pests than lower–yielding traditional varieties. This justifies that intensifying grain yield without proper modeling of their storage qualities may not be the only solution. There are multiple and interacting factors that shape farmers’ decisions at postharvest handling and management of maize grain. Food security does not just end at harvest as storage insect pest can cause significant postharvest losses of up to 30% in six months of storage (Boxall, 2002). Farmer’s willingness and ability to store produce definitely defines marketing trend and price variability which are a function of accessibility to appropriate storage practices and full involvement in the market chain in a beneficial way (FAO, 2015). Maize store–time as a prime factor in grain businesses has attracted little attention in postharvest management studies in most of the developing countries regardless of their potential contribution to marketing models. In most studies, storage losses and technologies are covered in the general storage cost (Brennan, 1958; Renkow, 1990; Saha and Stroud, 1994) to the extent that there is no measure of the isolated effect of storage losses so as to bring up suitable storage practices.

Time component in maize postharvest interventions and how it would influence farmers' economic decisions is crucial. One way to describe that is through a marketing model.

In Tanzania there are a number of marketing models that have been described FAO (2015). The common ones are Professional Maize Growers' Associations, Grassroots organizations e.g. Kibaigwa International Grain Market, Warehouse Receipt Systems and Mobile Phone Market Information. Despite reports of these models, the local maize markets have little or no indication of standard prices. Contrarily to the fact asserted by Mwakajage (2010) that, availability of improved markets facilities would ensure better producer prices. The prevailing models do not address some of the maize store–time challenges such as; the relationship between storage cost and total farmer income, the recommended amount of maize to be stored with regards to maximum profitability, recommended selling price after storage, the established maximum level of postharvest loss, and recommended storage practices for quality maize.

This gap pauses a need for a well sound maize store–time marketing model to address these issues as time key input in the marketing model of this nature. Participation of smallholder farmers to markets has mostly been affected by existing marketing system which is typically characterized by; high distribution margins, seasonal price variability, poor rural transport infrastructure (Teravaninthorn and Raballand, 2009), and Lack of efficient storage infrastructure and poor market practices (Eskola, 2005; URT, 2008). Thus, this study formulated a maize marketing model based on farmer's store–time that can optimize their household incomes. The study has generated relevant information to be used by diverse decision support systems in the maize value chain.

1.3 Research Objectives

1.3.1 Overall Objective

The general objective of this study was to formulate a maize store–time marketing model so that maize production farmers can reduce post-harvest and market losses of their produce particularly the Northern zone of Tanzania.

1.3.2 Specific Objectives

- i. To map the operating maize storage structures in the Northern Zone of Tanzania.
- ii. To assess average postharvest losses under the prevailing storage structures with respect to store–time.
- iii. To assess stored grains moisture trends under prevailing storage structures and its contributions to maize postharvest losses.
- iv. To examine maize return on investment with regards to household maize store–time.
- v. To formulate maize store–time marketing model for household’s income optimization.

1.3. Research Questions

- i. What are the prevailing maize storage structures in the Northern Zone of Tanzania?
- ii. What is the average postharvest loss of the current maize storage techniques under different store–time?
- iii. Are there any significant moisture trends on the stored maize grains under the prevailing storage structures? If so, what are their contributions toward maize postharvest losses?
- iv. What is maize return on investment with regards to household maize store–time?
- v. What is the appropriate maize store–time marketing model for the household’s income optimization?

1.4. Significance of the Research

The study brings the better understanding of the contributions of the maize store –time marketing model to the small–scale farmers, for use as a decision supporting tools so as to raise their incomes, profits and minimize postharvest maize losses. Considering the contributions of store-time in maize as an investment, the study creates awareness in the profitable store-time for household income optimizations Tanzanian government as well as other maize stakeholders.

1.5. Limitations of the Study

The household involvement throughout the study period was voluntary, some of them sold all of their maize stock before the agreed store-time resulting into insufficient individual household data. However, the missing information has been supplemented during focused group discussions. This study adopted random sampling method during household selection,

therefore most of the households were so scattered in a diverse wards and villages, some of them found to be in a very remote areas which increased the data collection cost. However, we managed to secure additional research funding from TAMASA project. Furthermore, this study intended to employ multivariate regression linear models following stepwise regression as model selection algorithm, unfortunately, the algorithm was highly sensitive to the number of observations resulting into failure in generating appropriate model for Kihenge which was employed by only 1% of the surveyed households. Alternatively, histograms were generated and the conclusions were drawn based on the height of the bars.

CHAPTER TWO

LITERATURE REVIEW

2.1. Postharvest Losses due to Poor Storage Technologies

Maize storage plays a vigorous portion in food supply series besides postharvest pipeline, thus it has a great role in the stability of food security. In most cases, soon after harvest; grains are subjected to storage for either short or long periods as food reserves and/or seeds. It has been reported that maize losses amounts to approximately 40% occur during postharvest operation; particularly due to use of poor storage facilities (Aulakh and Regmi, 2013; Majumder *et al.*, 2016), used. In developing countries about 50%–60% of the grains are stored in the traditional structures at the household and farm levels for self-consumption, and seed (Grover and Singh, 2013). The indigenous storage structures are made of locally available materials i.e. grass, wood, and mud without any scientific design, thus, cannot guarantee crop protection against pests for a long time. Teferra and Abass (2012) and Costa (2014) in their study reported that maize postharvest losses reached as high as 59.5% after storing grains for 90 days in the traditional storage structures which are exceedingly prone to pest invasion. With regards to this trend, the efforts devoted by farmers would end up being feeding insect pests instead of the intended human community in one hand and hidden hunger on the other.

In addition to limited accessibility to the improved storage facilities, farmers lack knowledge on safe grain moisture levels (and other conditions such as temperature) that would allow safe storage. For instance, it is highly recommended that harvested crops be dried to safer moisture levels of 10–13% for cereals and 7–8% for oilseeds almost immediately next to harvest (Waliyar *et al.*, 2015). If this moisture level is not reached, molds can grow on kernels especially under appropriate temperature of about 25C-30C. At lower temperatures and moistures molds do not grow, for example, Proctor (1994) asserts that grain maize might be kept for a year at a kernel moisture level of 15% and a temperature of 15°C without any fungal development. Hence, farmers' understanding of the biophysical component of the maize storage ecosystem is a key to minimizing post-harvest loss. All along, the physical, inorganic and organic characteristics of grain sidelong to ecofriendly settings during growth, harvesting methods and handling practices prior to storage influence storability (Zhang *et al.*, 1992). For this matter, farmers should put ample work on grain sorting to minimize threat debris, broken seeds, chaff and dust to improve aeration in store.

2.2. Postharvest Loss due to Storage Fungi

The postharvest loss of maize in humid nations are contributed by biological and environmental factors, for this case, insect pest and molds are among the biotic factors (Muir *et al.*, 2010) whereas abiotic aspects are moistness and hotness (Giorni *et al.*, 2008). The interface between these elements determine the occurrence of fungi and their relative development during storage (Cairns–Fuller *et al.*, 2005), hence, there should be a clear match between these interactions for the loss to occur. The storage fungi comprise, mainly, several species of *Aspergillus* such as *A. amstelodami*, *A. chevalieri*, *A. repens*, *A. restrictions*, and *A. ruber*, plus *A. caltdidus*, *A. ochraceus* and *A. flavus*. Of these fungi, the most potent is *A. flavus* as it has concerns of food safety and nutrition security, health and barriers to trade. Key postharvest losses as a result of storage fungi are; decrease in germination percentage; grain quality deterioration, grain biochemical changes, and toxins that constitute healthy risks for human being and animals. Additionally, already invaded maize by storage fungi deteriorate much more rapidly after being stored under favorable environment meant for fungi breed contrary to grains which are not invaded (Christensen and Kaufmann, 1968). Therefore, it is highly emphasized that growers should be well equipped with all necessary familiarity and expertise related to storage fungi to reduce postharvest losses and raise their income levels to improve their livelihoods.

2.3. Postharvest Loses due to Common Storage Insect Pests

Insect contributes highly in PHL through boring within the kernels and feeding on the surfaces remove food and selectively consume nutritive components and encourage higher moisture inside the kernel which proliferates secondary insect pests and microorganisms. These Biophysical conditions of grain maize before, at and slightly after harvest have a final bearing on its susceptibility toward pest occurrence during storage. Dowell and Dowell (2017) reported that, some of the common grain insect pests for maize are; the lesser grain borer (*Rhyzopertha dominica*), maize weevil (*Sitophilus zeamais*), and red flour beetle (*Tribolium castaneum*). Additionally, *Sitophilus* (Curculionidae), *Tribolium* (Tenebrionidae), *Sitotroga cerealela* (Grain Moth), Grain Weevil *Sitophilus granarius* (L.) the prime storage insect pests in SSA (Dick, 1988; Holst *et al.*, 2000), the Larger Grain Borer (LGB) *Prostephanus truncatus* (Horn), (Bostrichidae) (Nyambo, 2008). A study steered in Tanzania by Suleiman and Rosentrater (2015) shows that; farmers storing cassava and maize in Tabora region experience a severe damage up to 30% of the stored grains and some experience extreme case, whereby, grains were fit for neither seed nor consumption hence regarded as

total loss just 90 to 180 days of storage, in the cause of unfamiliar beetle subsequently identified a *P. truncatus*. In most parts of SSA, one way to inhibit invasion of storage insect pest in maize is to combine with some other grains i.e. teff, which seals the intergranular spaces precluding insect pest devastation (Haile, 2006). Definitely, the circumstances with maize to manipulate kernel storage micro-ecosystems to manage PHL due to storage insect pests are diverse. These manipulations are suggested and should be communicated with smallholder farmers.

Apart from grain loss of quantitative, qualitative and goodwill, some grain-infesting insects harbor in their gut potentially harmful microbes. Some of these include bacteria, such as pathogenic *Salmonella* (a common cause of food poisoning, found in insect feces), hemolytic *Streptococcus*, and *Escherichia coli* (also from insect feces), and they may well harbor also some viruses capable of infecting man or his domestic animals (Christensen and Kaufmann, 1969). These scenarios may have multiplier effects that should be considered when managing socio-economic of maize postharvest loss.

Perversely, agriculturalists in SSA are facing problems of accessing the recommended pesticide of the original quality at reasonable price, whereby some farmers have been experiencing grain loss regardless of insecticide applications; hence the problem remains unsolved. Unfortunately, farmers lack knowledge on the precise chemical, right timing, right dosage and right place/location in the application of insecticides. All these have led to unjudicious use of insecticide including threats to human and livestock health, impaired trade due to insecticide residues, water pollution, and biodiversity loss. Therefore, designing an improved maize marketing model with the justifiable store-time would be a solution to justify the storage cost and expected a return on investment to speed up the profitability of the maize subsector. A successful model may serve as a decision supporting tool for scaling up widely to appropriate areas in the country.

2.4. Postharvest Losses in relation to Store-time and Price

In SSA, normally farmers have a minimum of seven months maize store—the time between two yield seasons. Alternatively, some farmers sell their crops in a little while they reap about 54% and 38% to cater for domestic and school fees consecutively, even though maize prices can increase meaningfully in the period of 180 days of storage (Abass *et al.*, 2014). A different study conducted in Kenya, links unpleasant selling price with poor storage facilities

in the combination of improper storage store administration skills resulting into immediate sales after harvest (De Groote *et al.*, 2013), which makes maize to fetch low price with regards to law of demand and supply i.e. If demand decreases and supply remains unchanged, then it leads to lower equilibrium price and lower quantity.

An immediate sale after harvest may justify low profit. Promising store–time marketing model would stand as a way forward to maximize profit gained by farmers. Furthermore, another survey conducted in Uganda to determine the effect of the store–time on price for smallholder farmers reveals a significant correlation between store–time and gained profit. From the study, it has been observed that the majority of maize harvested in December 2013 was sold directly to moderate postharvest losses, whereby, maize in the initial weeks of January 2014 expected range of UGX 480 and UGX 520 per kg, whereas manipulating the better storing equipment fair three months far ahead, April 2014, anticipated around UGX 760 and UGX 820 (Costa, 2014). Furthermore, an increment of 64% would be raised as additional earnings for a particular family. Hence, accessibility to proper storage facilities would improve farmer’s waiting–time as a means of solving maize price fluctuations and generating high profit.

In addition, as maize becomes scarce its price shoots up; Chapoto and Jayne (2009) in Malawi assert that real maize prices typically double in 24 weeks after harvesting season. Also, Didier *et al.* (2013) conclude that price variation drives the storage decision; from the study, 1% increase of the expected in future price result into an increase of 8.4 kg of the average quantity stored. Therefore, the household could increase profits by holding maize stocks until later in the marketing year because the market price would rise accordingly as maize becomes scarce. Moreover, devaluation of maize grain quality in the cause of PHL leads into price discount as pointed out by Didier (2013) that is, 1% raises in kernel injury leads to down price for about 0.32%. Hence, it justifies the improvement in storage structures together with the store–time so that crops may fetch better prices and generate more income. The present study suggests that resilient postharvest strategies together with an improved storage method need to be established and defended with a reasonable store–time to secure both income and nutrition security in the postharvest period. These would serve as farmer’s decision supporting tools on taking farming as an investment.

2.5. Postharvest Loss in relation to Marketing Model

In SSA, maize prices are highly determined by market forces (demand and supply) though maize shortages and maize price instability persist (Chapoto and Jayne, 2009). A lower maize price definitely affects all households that participate in maize markets both positively and negatively. In SSA maize profitability is regularly a gathering of carrying costs, capital rewards, and transactions costs. From the study on maize three-dimensional market assimilation in Malawi and Zambia (Goletti and Babu, 1994; Chirwa, 1999; Tostao *et al.*, 2006; Abdulai, 2007; Myers, 2013; Burke, 2012; Mason *et al.*, 2012; Ricker-Gilbert *et al.*, 2013) and for the wider region (Rashid, 2010; Mulenga and Campenhout, 2008) found that, efficiency in maize market functions increases over time with decreasing marketing costs.

This is to say; with the aid of a well-established marketing model the mentioned achievement would become more consistent in SSA resulting in commercial farming of maize. Additionally, through modeling the effect of store-time on maize prices (specifically in *spatial-temporal* scenarios) i.e. linkage between domestic prices (inter-village) and prices in regional markets (across region) should be accounted well to justify their linkage considering positive association among price and market participation i.e. the implication is that effectiveness of price incentive in maize marketing model is highly influenced by smallholder farmer's store-time and market spatial integration.

Basing on research conducted in Malawi by Chirwa *et al.* (2010); relate increased maize prices with improved maize yields:

- i. increased maize exports and purchases for the strategic grain reserve;
- ii. rising real household income and
- iii. increased storage losses due to long store-time.

From a business perspective, the concentration of very few sectors in the marketing channels would raise the rate and proportion of prices response (Miller and Hayenga, 2001), thus long maize store-time with a significant contribution in a PHL. Therefore, maize-store time and its marketing environment should be modeled to allow a reasonable store time for a profitable return to maize investment. The researched model would be the key decision support tool to policymakers and actors to improve the profitability of maize businesses inappropriate time and place in the region. Basically, the system should aim at boosting market functions that

improve farmer's revenue against returns on investment and incentivize farmers to participate in markets.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Study Location and Materials

This study was conducted in the Northern Zone of Tanzania particularly in Manyara, Arusha and Kilimanjaro regions. Three Districts were purposively chosen in each of the three regions. The Districts by regions include: Manyara (Babati, Hanan’g, and Mbulu), Arusha (Monduli, Arumeru and Karatu), and Kilimanjaro (Siha, Hai and Moshi rural) (Fig. 1). The Districts were selected due to the fact that they are the major maize growing areas of the north Tanzania, and also based on their production statistics and preference by Taking Maize Agronomy into Scale in Africa (TAMASA) project which funded this research

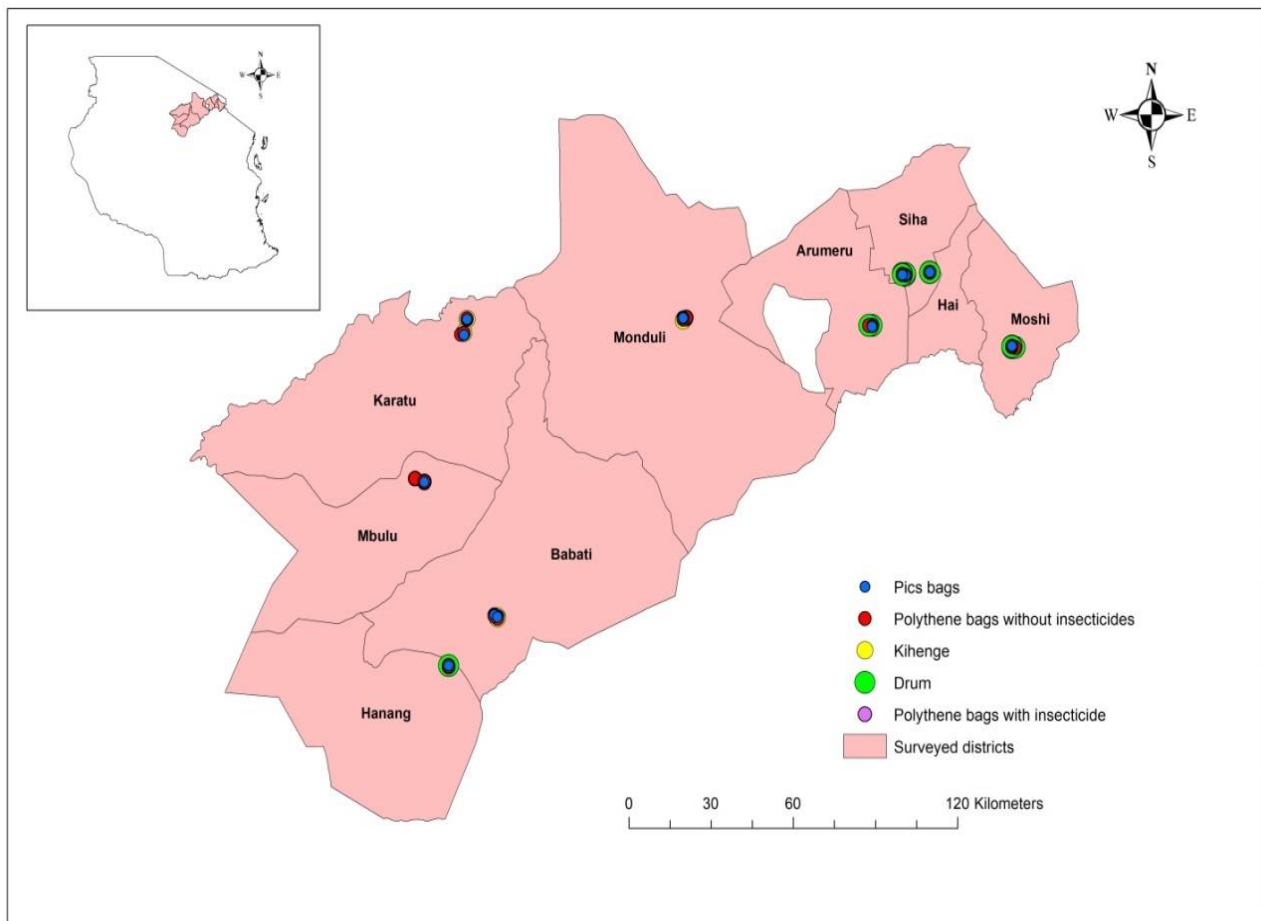


Figure 1: Maize storage structures in the Northern Zone of Tanzania

3.2. Household Sample Selection

The sampling frame was the maize farming households in the study Districts. Random sampling from 10 km x10 km grids was established in the study Districts based on GPS

coordinates. From each 10 km x 10 km grid, three 1 km x 1 km grids were randomly selected. In each of these 1 km x 1 km grids, 10 households were randomly selected for enumeration. A survey included 270 maize growers out of 94 782 households in the Northern zone. The survey was conducted between August 2017 and May 2018. Semi-structured questionnaires were used to collect data on the household social economic profile, marketing aspects and number of farmers growing different crops in the study area growing different crops. In total, 591 farmers were covered out of 94 782 households for this assessment. In addition to the household interviews, Focus Group Discussions (FGD) was conducted, with the involvement of Agricultural extension staffs so as to get in-depth qualitative information of storage structures and their management. After the survey, four households were purposely selected based on their maize storage volume and type of storage structure or methods used. Then the identified methods were used for the study to assess the efficiency of the storage structure.

3.3. Experimental Design

The study adopted Randomized Complete Block Design (RCBD) as experimental research design so as to minimize the chances for statistical and experimental errors. The experiment consisted of five treatments evaluated in four replications. The treatments were:

- T1: Polyethylene bags without insecticides (untreated control);
- T2: Polyethylene bags with insecticide (Actelic supper or Shumba);
- T3: Metal Drums without insecticide;
- T4: Kihenge without insecticide and
- T5: PICS bag without insecticide.

A piped iron stick of about 0.5 m long and 3.5 cm in diameter was used to draw 1 kg/household of the maize grains from the top, middle, and bottom of each of the identified storage structure. In total, four maize samples representing four replications were collected in each 10 km x 10 km sampling location. Maize samples were kept in paper bags to prevent moisture alteration and transported to the NM-AIST laboratory for assessment. The same procedure was repeated throughout six-months consecutively i.e. from November 2017 to April 2018. In addition as back up, 100 kg of maize grains/treatment from farmer's preferred maize variety were used to test effectiveness of the treatments i.e. in Polythene bags with insecticides, Polythene bags without insecticides (Actelic Super and Shumba from well certified/ registered Agro-dealers depending on farmer's storage preference in each district and rates of insecticide application were based on manufacturer recommendations). PICS

bags, Metal Drums filled to their full capacity depending on their sizes and Kihenge also filled to their capacity by farmers. In all cases, the researcher ensured maize grains for all the study farmers were standardized for the required quality to allow for the present experiments.

3.4. Maize Grain Sample and Data Collection

A random sample of 1kg grains was drawn from each of storage structures/methods and evaluated for insect damaged kernels. A handheld Grain Moisture Tester (MINIGAC1) was used to collect kernel moisture content. Kernel moisture data were collected on monthly bases from November 2017 to April 2018. Sampled grains were sorted to separate the unbored grain and insect damaged kernels, thereafter counted to calculate the percentage of insect damaged kernels in the sample following formula by Harris and Lindblad (1978).

$$\text{Percentage of insect damaged kernels} = \frac{\text{Number of damaged grains}}{\text{Total number of grains counted}} \times 100\%$$

3.5. Data Analysis

The data were processed and entered into an MS Excel 2010 spreadsheet and analyzed using R statistical software version 3.5.1. Statistical parameters such as frequency distribution table, descriptive statistics tables, Correlation tests, multivariate regression, *P*-values, Coefficient of determinations (R-squared), Akaike Information Criteria (AIC) and variables coefficients were input in model selection criteria based for a Stepwise Regression algorithm. Multivariate regression models were employed leading into the evaluation of maize postharvest losses under selected storage structures with respect to store time, so as to establish levels of maize grains postharvest loss on the identified storage structures with regards to store time. Significant differences in insect-damaged kernels parameters were concluded based on the statistical significance levels of their coefficient of the interaction at *P*-values ≤ 0.05 . Furthermore, the Multicollinearity and significance of the predictors were tested based on the Variance Inflation Factor (VIF) for each predictor in the model as suggested by Zuur *et al.* (2010).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Results

4.1.1. Maize Storage Structures in Northern Zone of Tanzania

The results show that, five storage structures/methods namely *Kihenge*, Metal drums, PICS bags and Polyethylene bags with and without insecticides have been identified (Fig.1 and Plate 1). Polyethylene bags and PICS bags were found to be the most dominant structures in most sites; Metal drums were common storage structure in Siha, Hai and Moshi rural while *Kihenge* were dominant in Babati, Karatu and Monduli as clearly shown in Fig. 1.

The results also indicated that the majority of the maize growers in the study area employ more than one storage structure/method at a time based on the storage purpose and the harvested volumes (Fig. 2). The most predominant storage structures among sampled households were the Polyethylene bag without insecticide treatment amounting (63%). The second common storage structures were Polyethylene bag with commercial insecticide Shumba or Actellic dust (Fig. 2). Polyethylene bags were either stacked on the floor in an upright position or stacked on top of one another in the kitchen area or in an empty room depending on the number of harvested bags. The *Kihenge* were established close to farmhouses and were observed to be relatively inexpensive in terms of materials, though its construction requires intensive labor. The size of the structures was flexible and based on the grains volume to be stored. This storage structure was not dominant and counted for about 1% of the respondents and they were mainly found in Karatu, Hanang and Babati Districts. Maize grains stored under these structures were not treated with any kind of insecticides.

Another storage structure identified in the study area was Metal drums. This structure was highly dominant in Siha and Hai Districts and it accounted for about 7% of the respondents. The capacity of one Metal drum was about 180 kg. Maize grains stored in Metal drums were not treated with insecticide or any other treatment and they were mainly kept for household food consumption. The fifth storage structure identified was PICS bags. This structure was adopted by 13% of the sampled households; grains stored were mainly for food consumption.

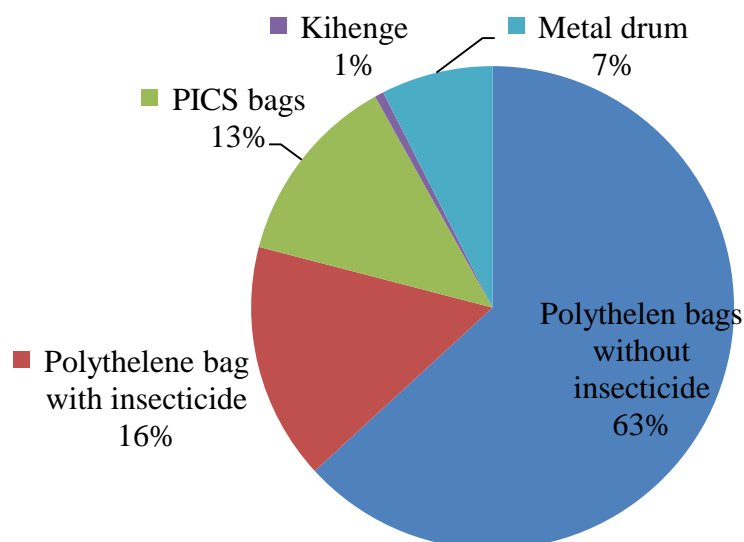


Figure 2: Distributions maize storage structures in the Northern Zone of Tanzania

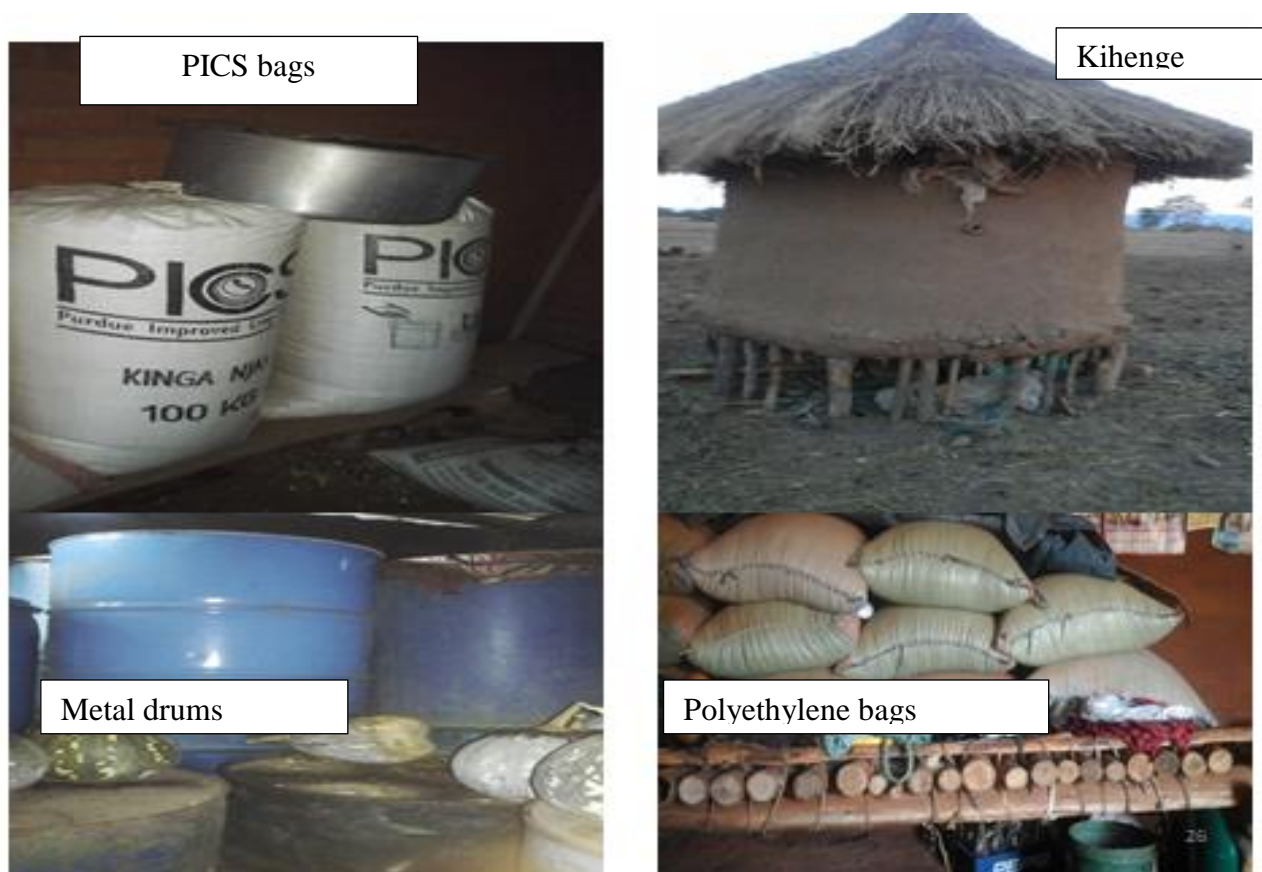


Plate 1: Different storage structures identified during the study

Above pictures displays five identified storage structures, there were no separate room for maize storage, the store-room were multipurpose with a lots of stuffs together with maize which might attract destructive organisms such as rodents.

4.1.2. Household Livestock Value in Relation to the Storage Structure

The results also showed that there was an association between household with livestock and the application of insecticides (Shumba or Actelic dust) as one of storage method $\chi^2(233) = 279$, $P = 0.021$). Furthermore, there was a strong correlation between quantity harvested and quantity of maize stored ($r = 0.96$, $P < 0.001$) and also a strong association between quantity stored and quantity sold with ($r = 0.8$, $P < 0.001$) as shown in Table 15.

4.1.3. Social Economic Profile of the Study Area

The majority (67%) of respondents had Primary Education and only few had education levels higher than Primary education (Table 1 and Fig. 3). Both males and female were highly involved in the study even though males comprised of 52% of respondents. The majority of respondent were within the age of 15–35. About 61% of the respondents were married. About 90% of the respondents were not employed and 44% of respondents were food secure (Table 1). Other social characteristics are as presented in Table 1.

Table 1: Household demographic characteristics of respondents

Variable	Levels	Percentage
Education	None	10
	Primary	67
	Secondary	18
	Post-secondary	5
Gender	Male	52
	Female	48
Age	15 –35	53
	36 –55	34
	56 –75	10
	76 ⁺	3
Marital status	Married	61
	Single	34
	Widow	4
	Separated	1
Relationship to the HH	child	35
	Household head	30
	Spouse	28
	Others	7
Informal income earned	Yes	10
	No	90
Wage earned	Yes	7
	No	93
Health status	Yes	92
	No	8
Rent Land availability	Yes	81
	No	19
Social groups	Yes	35
	No	65
Food security	Yes	44
	No	56
Price sources		
Middlemen prices	Yes	52
Neighbour prices	Yes	48
Market sources		
Middlemen	Yes	96
Market place	Yes	4

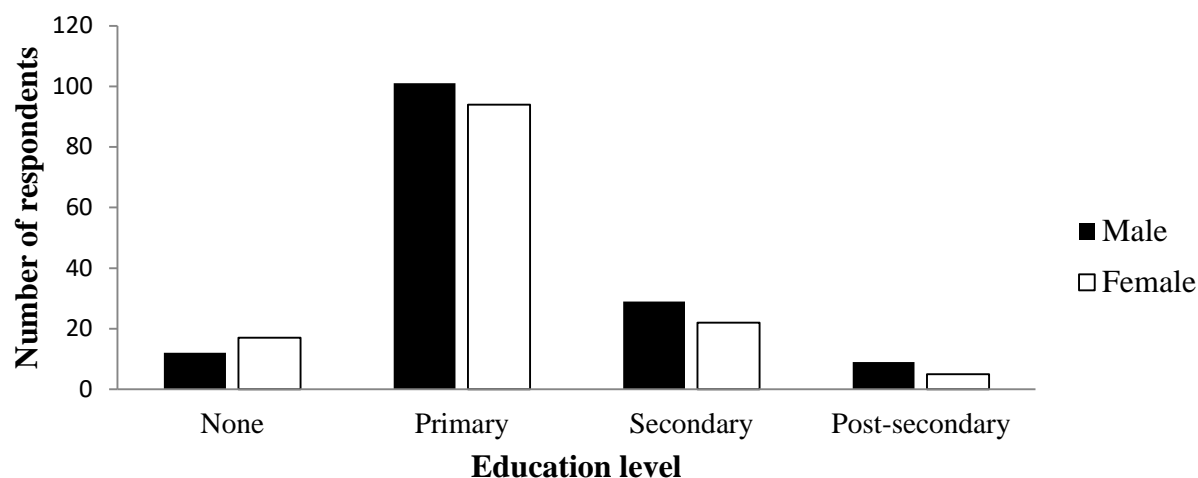


Figure 3: Education level of respondents covered in this study

4.1.4. Crops Production Trend for 2017/18 Season

From the descriptive statistics (Table 2) maize was the main crop produced by the majority (45.5%) of the farmers with a production average of 2 013 kg per acre household during the 2017/18 cropping season generating an average of 1 221 017 Tanzanian Shilling (TSH) per household. The price and total income from other crops in the study area Table 2.

Table 2: Crops Production Trend for 2017/18 Season

Crop	Percent age	Average harvest/kg/household	Average Price/kg	Average income/Tsh/household
Maize				
e	45.5	2013	577	1 221 017
Sunflower	8.6	1387	2130	2 954 310
Tomatoes	2	1286	345	9 815 154
Beans	12.5	513	1354	576 572
Pigeon peas	15.4	466	1366	679 846
Coffee				
e	2.4	425	2873	921 220
Irish potatoes	4.7	427	439	1 787 900
Other Crops	9.9			

4.1.5. Average Income from Different Sources

Data on average income from different sources is presented in Table 3. Livestock had the highest value (9 362 900.00 TSH) followed by off farm income (670 600/year) while income from gifts was the lowest as it was only (18 700 TSH). The values of other income generating activities are as shown in Table 3.

Table 3: Average Income during season 2017/18 cropping season

Sources	Average [†]
Off-farm income	670 600/year
Wage and salaries	142 500/month
Remittances	61 039/year
Business	566 950/year
Land rent	69 000/year
Gift	18 700/year
Livestock value	9 362 900.00

[†]The average value was calculated by total value of counted source entities in all household divided by number of household in the study area.

4.1.6. Access to Social Services by Households in Northern Zone of Tanzania

Majority of social services can be accessed by the household with an average distance ranging from 2.8 km to 7.7 km. However, few households were located up to 48 km away from social service centers (Table 4).

Table 4: Access to social services in the Northern zone of Tanzania for season 2016/17

Services	Mean distance/Km	Median distance/Km	Maximum distance/Km
Distance from household to the animal market	6.5	5	40
Distance from household to a water source	2.8	0	13
Distance from household to crop market	5.4	4	40
Distance from household to fertilizer shop	7	6	40
Distance from household to certified seed shop	7.7	6	48
Distance from household to health centers	3.6	2	35
Distance from household to extension services	3.2	1	40
Distance from household to the tarmac road	0.3	5	13
Distance from household to electricity sources	3.4	1	25

4.1.7. Household Store–time in Relation to Demographic Characteristics

Using the chi-square test, two demographic variables were found to have significant associations with their store–time. The variables were; household education level with $\chi^2(16) = 29.31$, $P = 0.02$ and household head marital status $\chi^2(20) = 40.33$, $P = 0.005$ as shown in Table 5.

Table 5: Association between household store–time and demographic characteristics

Demographic characteristics	χ^2 -value	P-value
Family size	22.9	0.5
Food security	4.3	0.4
Crop sales	3.9	0.4
Total harvest	20.8	0.6
Education level	29.3	0.02*
Informal income	1.2	0.9
Marital status	40.3	0.005***
Gender	0.5	0.9

*** and * = significant at $P \leq 0.001$ and 0.05 respectively.

4.1.8. Maize Postharvest Losses under Storage Techniques with Respect to Store–Time

(i) Maize Insect Damaged Kernels under Different Storage Structures

From the correlation matrix shown in Table 6, Polyethylene bags without insecticide had high grain damage with large coefficient of correlation (0.516) and a significant P –value of 0.0001, while the least grain damage was found to be on PICS Bags with insignificant coefficient of correlation of -0.378 (Table 6). Similar results were observed from the total loss percentage calculated, whereby Polyethylene bags without insecticide had about 43% of insect-damaged kernels while insect damaged kernels under PICS bags were 1% (Table 7).

Table 6: Association between storage structure and insect damaged kernels

Structures	Metal drum	Polyethylene 1	Kihenge	Polyethylene2	PICS Bag	%I DK
Metal drum	1.000					
Polyethylene1	−0.267	1.000				
Kihenge	−0.086	−0.097	1.000			
Polyethylene 2	−0.334	−0.380	−0.122	1.000		
PICS Bag	−0.260	−0.296	−0.095	−0.371	1.000	
%IDK%	−0.272	0.037	0.045	0.516	−0.378	1.00
P-values	0.114	0.001***	0.001***	0.001***	0.0787	

*** = significant at $P \leq 0.001$, Polyethylene 1= Polyethylene bag with Insecticide, Polyethylene 2= Polyethylene bag without Insecticide, IDK = Insect damaged kernels

From the results, PICS bags and metal drum were found to have no association with numbers of insect-damaged kernels with a correlation of coefficient −0.38, −0.27 respectively and P -value >0.05 (Table 6). However, polyethylene bag without insecticide were found to have a strong association with insect-damaged kernels with a correlation of coefficient of 0.52.

Table 7: Insect damaged kernels in storage structures in 2017/18 cropping season

Storage structure	Total sampled grains	*Total insect damaged kernels	**% insect damaged kernels
PICS Bags	1kg	121	1
Metal drums	1kg	484	4
<i>Kihenge</i>	1kg	2783	23
Polyethylene bag with Insecticide	1kg	3509	29
Polyethylene bag without Insecticide	1kg	5203	43

* Total Damaged grains were counted throughout six months consecutive, **Insect damaged kernels %= (Total insect damaged kernels/ Total grains)*100

(ii) Maize Insect Damaged Kernels under Different Storage-time

Results indicated that maize can be stored in the PICS bags throughout six-month store-time with minimum insect damaged kernels, contrarily to Polyethylene bag without insecticide which showed a significant increase in insect-damaged kernels as store time increases Fig. 4.

In this figure, experiments were set in November 2017 and monitored monthly for six month until April 2018. It was clear that, normal bags without insecticides was consistently inferior to other methods and high infestation was noted as of month one (i.e. November 2017) as shown in Fig 4.

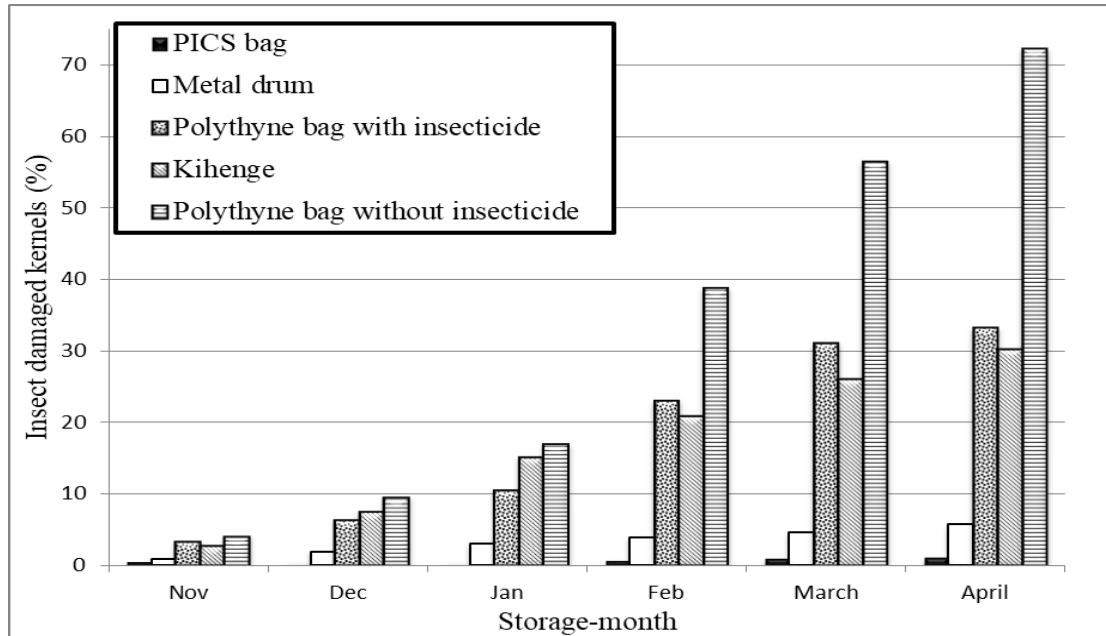


Figure 4: Insect damaged kernels and store-time during the 2017/18 season

(iii) Maize Postharvest Loss under PICS Bags for Six Month Store-time

To evaluate the interactions between store–time (in six months) and insect damaged kernels under PICS bag, the multivariate linear regression model was performed. Total insect damaged kernels on January, February, and April was found to be significant based on Stepwise Regression model selection criteria with their coefficients -0.12 , 0.08 , -0.02 and P –values of 0.01 , 0.05 , 0.05 respectively as shown in Table 8 and Model 1. Furthermore, the model scores -135.09 Akaike Information Criteria (AIC) with an Adjusted R–squared 0.06 and P –value 0.06 , on 3 and 62 degrees of freedom. From the Multivariate Linear Regression Model 1 have been generated to show the relationship between variables:

Table 8: Maize Postharvest Loss under PICS Bags for in 2017/18 cropping season

Coefficients	Estimates	Std.Error	t-value	P-value
Intercept	8.181826	0.050593	161.718	0.001***
IDK (January)	-0.118456	0.045135	-2.624	0.01**
IDK (February)	0.081999	0.042052	1.950	0.05*
IDK (April)	-0.018865	0.009618	-1.961	0.05*

***, **And * = significant at $P \leq 0.001$, 0.01 and 0.05 respectively. X=Insect damaged kernels with respect to store-time, Y=Total insect damaged kernels under PICS bag, IDK= Insect damaged kernel

$$\text{Model 1: } Y_{\text{Jan, Feb, April}} = 8.18 - 0.12x_{\text{Jan}} + 0.08x_{\text{Feb}} - 0.002x_{\text{April}} + C$$

(iv) Maize Postharvest Loss under Metal Drum for Six Month Store-time

Multivariate linear regression model has been generated to shows the interactions between insect damaged kernels and store-time in evaluating total insect damaged kernels under Metal Drum (Table 9). From the results, maize insect damaged kernels under Metal Drum had coefficients of 0.12, -0.02, -0.06, 0.06 and -0.02, and , P -values of 0.01, 0.09, 0.01, 0.03 and 0.05, for Nov, Dec, Jan, March and April respectively. In additional, the model had AIC -164.8, Adjusted R-squared was 0.42 with P - value of <0.001, on 5 and 60 degrees of freedom. Also from the Multivariate Linear Regression Model 2 have been generated to show the relationship between variables.

Table 9: Maize Postharvest Loss under Metal Drum in 2017/18 cropping season

Coefficients	Estimates	Std.Error	t-value	P-value
Intercept	8.033959	0.040561	198.072	0.001***
IDK (November)	0.123834	0.027238	4.546	0.001***
IDK (December)	-0.029301	0.017265	-1.697	0.09
IDK (January)	-0.056448	0.017459	-3.233	0.001***
IDK (March)	0.056681	0.018410	3.079	0.01**
IDK (April)	-0.018477	0.009217	-2.005	0.05*

***, ** and * = significant at $P \leq 0.001$, 0.01 and 0.05 respectively. X= insect damaged kernels under different store-time, Y= Total insect damaged kernels under Metal Drum, IDK= insect damaged kernels

$$\text{Model 2: } Y_{\text{Nov, Dec, Jan, Feb, April}} = 8.03 + 0.123834x_{\text{Nov}} - 0.029301x_{\text{Dec}} - 0.056448x_{\text{Jan}} + 0.056681x_{\text{March}} - 0.018477x_{\text{April}} + C$$

(v) Maize Postharvest Loss under Polyethylene bags for Six-Month Store-time

To evaluate the maize insect damaged kernels under Polyethylene bag (with and without insecticide) with reference to store-time, the results show that three month store-time was found to be significant for Polyethylene bag with insecticide, while bags without insecticide was only significant after one-month store-time (November) after which it was insignificant (Table 10). Furthermore, Polyethylene bag with insecticide had a coefficient of -0.03 with P -value 0.01 , Adjusted R -squared 0.08 and $AIC = -137.63$, while, Polyethylene bag without insecticide scores a coefficient of -0.07 , with P -value 0.01 , $AIC = -137.6$ and Adjusted R -squared $= 0.08$ (Table 10). Furthermore, from the Multivariate Linear Regression Model 3 have been generated to show the relationship between variables

Table 10: Maize Postharvest Loss under Polyethylene bags in 2017/18 cropping season

Coefficients	Estimates	Std.Error	t-value	P-value
Intercept (with insecticide)	8.242355	0.055938	147.347	0.001***
Intercept (without insecticide)	8.263875	0.061862	133.585	0.001***
IDK January (with insecticide)	-0.003121	0.001239	-2.518	0.01^{**}
IDK November(without insecticide)	-0.006950	0.002765	-2.513	0.01^{**}

*** and ** = significant at $P \leq 0.001$ and 0.01 respectively. X =Insect damaged kernels with respect to store-time, Y =Total insect damaged kernels under Polyethylene bag, IDK= insect damaged kernels

$$\text{Model 3: } Y_{\text{Jan}} = 8.242355 - 0.003121x_{\text{Jan}} + C; Y_{\text{Nov}} = 8.242355 - 0.006950x_{\text{Nov}} + C$$

(vi) Maize Postharvest Loss under Kihenge for Six Month Store-time

In the evaluation of maize insect damaged kernels as a result of interactions between *Kihenge* and store-time, multivariate linear regression was generated following stepwise regression model selection algorithm. The results showed that, there were no significant store-time under the *Kihenge* method. From the results, this storage structure had an intercept of 8.15 , with P -value < 0.001 .

4.1.9. Moisture Content Variations under Different Storage Structure and Store-time

To evaluate the contributions of interactions between moisture content trends during store-time and storage structure on maize postharvest losses, Multivariate Linear Regression was performed. The results show no significant variations in moisture contents in the selected storage structures except in Metal drum with a coefficient of 0.04 and a significant P -value < 0.01 throughout six-month store-time (Table 11).

Table 11: Interaction between Storage Structure and Stored Grains Moisture Trends

Coefficients	Estimates	Std.Error	t –value	P–value
Intercept	8.118699	0.078611	103.277	0.001***
PICS bags	–0.009196	0.007071	–1.301	0.1984
Polyethylene bag without insecticide	–0.009135	0.007675	–1.190	0.2387
<i>Kihenge</i>	–0.003937	0.014860	–0.265	0.7919
Polyethylene bags with insecticide	–0.004321	0.002401	–1.800	0.0769.
Metal drum	0.035733	0.007031	5.082	0.001***

*** = significant at $P \leq 0.001$.

4.1.10. Maize Return on Investment with Regards to Household Maize Store–Time

(i) Associations between Storage Cost and Storage Structures

The results show that there was associations between the household preferred storage structure and the involved storage cost throughout the store–time, whereby Polyethylene bag without insecticide scored a strong coefficient of correlation 0.77 with P –value < 0.01 ; Polyethylene bag with insecticide scored coefficient of correlation 0.09 with P –value of 0.04, Metal drum had 0.01 correlations of coefficient and 0.02 P –value. The PICS bags and *Kihenge* had insignificant P –values with 0.12 and –0.04 coefficients of correlation, respectively as presented in Table 12.

Table 12: Storage cost and storage structures association in 2017/18 cropping season

Variables	PICS bags	Polyethylene 1	Kihenge	Metal drum	Polyethylene 2	Storage cost
PICS bags	1					
Polyethylene 1	0.29	1				
Kihenge	-0.03	–0.1	1			
Metal drum	-0.12	–0.11	–0.09	1		
Polyethylene 2	0.22	–0.14	–0.03	–0.09	1	
Storage cost	0.12	0.77	–0.04	0.06	0.09	1
P –values	0.5	$<0.1e^{-4***}$	0.4	0.02*	0.004**	

***, **and * = significant at $P \leq 0.001$, 0.01 and 0.05 respectively. Polyethylene 1=Polyethylene bags without insecticide, Polyethylene 2=Polyethylene bags with insecticide.

(ii) Association between Store–Time and Storage Structure

The results showed that there was a significant association between store time and storage structures especially on Polyethylene bags with insecticide, with a coefficient of correlation of 0.23, P -value 0.05; Metal drum had a coefficient of correlation 0.17 with P -value of 0.03, Polyethylene bags without insecticide scored a coefficient of correlation of 0.14 with P -value 0.04. However, there were no significant associations between store time and PICS bags as well as *Kihenge* regardless of its positive coefficient of correlations of 0.19 and 0.07 respectively (Table 13).

Table 13: Store time and storage structures associations in 2017/18 cropping season

Variables	PICS Bags	Polyethylene1	Kihenge	Drums	Polyethylene 2	Store time
PICS Bags	1					
Polyethylene 1	0.29	1				
Kihenge	0.03	−0.10	1			
Drums	−0.12	−0.11	−0.09	1		
Polyethylene 2	−0.23	−0.15	−0.03	−0.09	1	
Store time	0.19	0.23	0.07	0.17	0.14	1
P -values	0.11	0.05*	0.3	0.03*	0.04*	

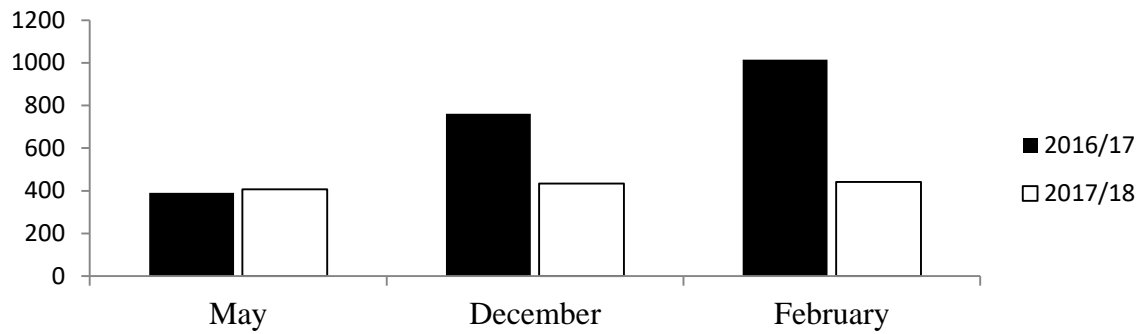
* = significant at $P \leq 0.05$ respectively. Polyethylene 1=Polyethylene bags without insecticide, Polyethylene 2=Polyethylene bags with insecticide.

(iii) Maize Price Trends between 2016/17 and 2017/18

Three months maize price trends i.e. May, February and December between 2016/17 and 2017/18 in the study regions were collected to assess the associations between household income and store–time with regards to the prevailing price. It was observed that, there were prices differences between two cropping seasons whereby maize prices in 2016/17 season were higher compared with 2017/18 (Fig. 5). Furthermore, 52% of the respondents depend highly on the middlemen as a source of price information, the rest 48% depends on their neighbors. However, there was no significant relationship between the quantity of maize sold in the household and the accessibility to price trends information with P -value: 0.56 and Adjusted R-squared -0.01 (Table 14).

Table 14: Maize price trends information in 2017/18 cropping season

Variable	Estimates	std Error	t-value	P-value
Intercept	1.03333	0.02262	45.691	<2e-16 ***
Price information (Neighbour)	0.03333	0.3148	-1.059	0.294
Price information (Middlemen)	0.03333	0.06595	-0.506	0.615

**Figure 5: Maize price trends in 2016/17 and 2017/18 cropping seasons.****(iv) Household Store–time**

The average store–time for the majority of the respondents (Fig. 6) were six months (70%); five months (8%); four months (15%), three months (6%) and one month (1%). Furthermore, from the correlation test, it was observed that there was significant difference between quantity harvested and store–time with P –value = 0.002 and coefficient of correlation = 0.4. Furthermore, there was a significant correlation between store–time and expected profit generated by the household with P –value of 0.03, coefficient of correlation of 0.3 as shown in Table 15.

Table 15: Household store-time and quantity harvested

Variable	Coefficient of correlation	Degrees of freedom	t-value	P-value
Qharvested and store time	0.3877695	64	3.3655	0.001296
Qharvested and stored	0.9744322	64	34.696	< 2.2e-16

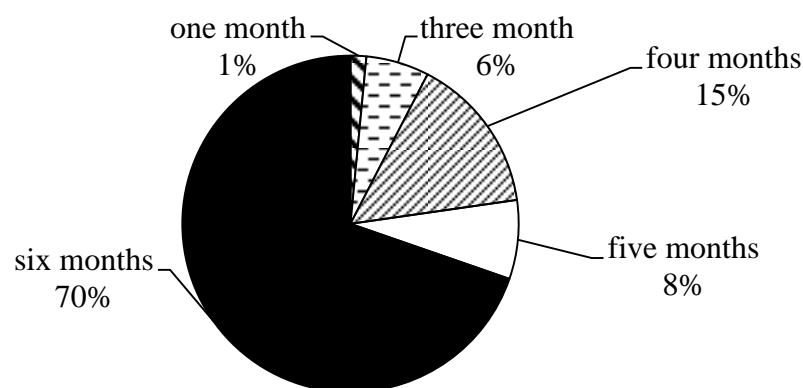


Figure 6: Household maize store-time in 2017/18 cropping season.

(v) Prevailing Marketing Channel along Maize Marketing Model

The results show that, there were maximum interactions between the majority of households and village grain assemblers as a crucial aspect of the maize marketing chain (Fig. 7). Despite the observed differences between farm–get price and market price of 5000Tsh/100 kg, yet, farmers depend highly on middlemen as a direct source of the market, about 94% of the respondent’s sale their maize direct to village assemblers while only 6% sale their maize grains direct to the market (Table 1). Furthermore, there was a significant relationship between marketing channels and income gained by household with P -value = 0.01, and Adjusted R-squared of 0.05 (Table 16).

Table 16: Marketing channels along marketing model

Variable	Estimates	std Error	t-value	P-value
Intercept	2271000	521688	4.353	4.94e-05 ***
Price information (Neighbour)	-1341569	538254	-2.492	0.0153 *

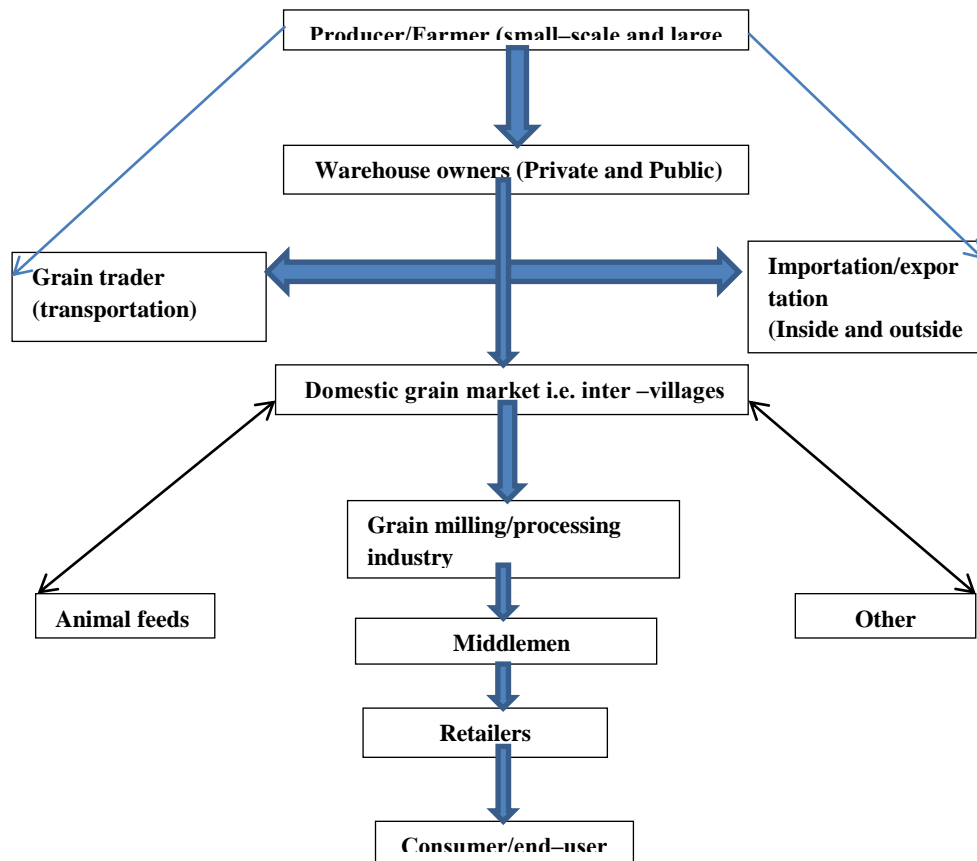


Figure 7: Hypothetical maize marketing channels in the Northern Zone of Tanzania

(vi) Return on Investment in Relation to Store–Time

The results for multivariate regression model generated showed that household can optimize their gain after storing maize grain for about five months store –time with highest coefficient of 0.71 and a very significant P -value of $< 2.2e^{-16}$. The expected profit gained in January has been removed from the model due to its insignificant AIC value considering regression stepwise model selection algorithms. However, profit gained on August was found to be the least based on its negative coefficient of -225.51 regardless of its significant P -value of 0.03. With regards to maize price trends, December and April were found to be beneficial sell–time to household income with 451.79, 368.8 coefficients and 0.01, $1.31e^{-13}$ P -values, respectively. The generated model was best fitted with the AIC of 1719.83, Adjusted R-squared: 0.8 and P -value of $< 2.2e^{-16}$ (Table 17). The Multivariate Linear Regression Model 4 has been generated to show the relationship between variables:

Table 17: Relationship between income and store –time in 2017/18 cropping season

Coefficients	Estimates	Std. Error	t-value	P-value
Intercept	-311371.65	75123.93	-4.145	0.00011 ***
Immediately sales (August)	-225.51	103.26	-2.184	0.03296 *
Three month store–time (November)	231.20	96.85	2.387	0.02020 *
Four month store–time (December)	451.79	163.90	2.757	0.00776 **
Five month store–time (February)	153.90	51.40	2.994	0.00402 **
Six months store–time (March)	318.83	107.16	2.975	0.00424 **
Seven months store–time (April)	368.80	38.54	9.568	1.31e ⁻¹³ ***

***, ** and * = significant at $P \leq 0.001$, 0.01 and 0.05 respectively, Y=Income, X=Predictors, X_{August} = immediately sales, X_{November} =Three month store –time, X_{December} = Four month store –time, X_{February} = Five month store –time, X_{March} = Six months store –time and X_{April} = Seven months store –time

Model 4: $Y_{\text{August, November, December, February, March, April}} = -311371.65 - 225.51X_{\text{August}} + 231.20X_{\text{November}} - 451.79X_{\text{December}} + 153.90X_{\text{February}} + 318.83X_{\text{March}} + 368.80X_{\text{April}} + C$

Following model verifications, multicollinearity and significance of the predictor variables have been tested so as to model linear independence of the predictors basing on the Variance Inflation Factor (VIF) for each predictor in the model. The summary of the presented Variance Inflation Factor (VIF) against the predictor is presented in Table 18.

Table 18: Summary of Significant and Multicollinearity test of predictors

Predictor	Variance Inflation Factor (VIF)
Immediately sales (August)	1.37563
Three month store–time (November)	1.493301
Four month store–time (December)	1.163675
Five months store–time (February)	1.203481
Six months store–time (March)	1.203408
Seven months store–time (April)	1.370387

4.1.11. Maize Store–Time Marketing Model on Household Income Maximization

From the study, maize return to investment was modeled following Multivariate Linear Regression. Later a stepwise regression algorithm was employed for model selection considering multicollinearity and significance of the predictor variables. Generated model was the best fit with Adjusted R–squared: 0.94, P –value < 2.2e–16 and AIC=1653.23 on 8

and 57 degrees of freedom. The significant relationships between household incomes with all selected variables are clearly stipulated in Table 19. The multivariate linear regression model 5 has been generated to show the relationship between variables.

Table 19: Maize Household income optimization model for Northern zone of Tanzania

Coefficients	Estimates	Std. Error	t-value	P-value
Intercept	$-5.575e^{05}$	$2.681e^{05}$	-2.079	0.0421 *
Storage cost	9.602	$9.128e^{-01}$	10.519	$5.70e^{-15}$ ***
Production cost	0.4314	$8.355e^{-02}$	5.164	$3.21e^{-06}$ ***
Maize sales (November)	$2.745e^{02}$	$6.043e^{01}$	4.543	$2.93e^{-05}$ ***
Maize sales (December)	$2.564e^{02}$	$9.863e^{01}$	2.600	0.0119 *
Maize sales (March)	$2.943e^{02}$	$6.619e^{01}$	4.446	$4.10e^{-05}$ ***
Maize sales (April)	$1.526e^{02}$	$3.529e^{01}$	4.326	$6.19e^{-05}$ ***
Selling price (January)	$1.397e^{03}$	$6.822e^{02}$	2.047	0.0452 *
Marketing cost	$7.740e^{01}$	$3.617e^{01}$	2.140	0.0367 *

*** and * = significant at $P \leq 0.001$ and 0.05 respectively. Y=Household income, X=predictors, SC=Storage cost, PC= Production cost, Sales1= November Maize sales, Sales2=December Maize sales, Sales3=March maize sales, Sales4= April maize sales, Price=January selling price and MC= Marketing cost.

$$\text{Model 5: } Y_{SC, PC, Sales1, Sales2, Sales3, Sales4, Price, MC} = -5.575e^{05} + 9.602X_{SC} + 0.4314X_{PC} + 2.745e^{02}X_{Sales1} + 2.564e^{02}X_{Sales2} + 2.943e^{02}X_{Sales3} + 1.526e^{02}X_{Sales4} + 1.397e^{03}X_{Price} + 7.740e^{01}X_{MC} + C$$

Furthermore, multicollinearity and significance of the predictor variables have been conducted to model linear independence of the predictors by calculating a Variance Inflation Factor (VIF) for each predictor to explain how the ratio of change in one predictor can be clarified by all the other predictors in the model. The summary of the presented Variance Inflation Factor (VIF) against the predictor is presented in Table 20.

Table 20: Summary of Significant and Multicollinearity test of predictors

Predictor	Variance Inflation Factor (VIF)
Storage cost	2.876558
Production cost	1.425516
Maize sales (November)	1.600415
Maize sales (December)	1.160120
Maize sales (March)	1.263786
Maize sales (April)	3.161490
Selling price (January)	1.042144
Marketing cost	1.527495

4.2. Discussion

This study find out that, maize store–time varies based on household educational status, as a matter of fact, levels of formal education ensure the ability to acquire, synthesize and apply the information gathered from various sources. Furthermore, education creates a broader network, therefore, reduces information searching cost as well as time taken to integrate and employ the acquired information on how long to store maize (Bywaters and Mlodkowski, 2012). In additionally, Thirtle *et al.* (2003) asserted that “well–educated farmers are well talented to integrate information and make use of new technologies due to their less vertical learning curve”. Considering the importance of maize store–time, farmer education needs to be given high consideration through awareness creations through making potential use of extension officers.

From the results, the surveyed respondent was diverse in their marital status. Basically, marital status can be taken as family size determinant and hence influences household maize decisions including store time, implying that there is a significant association between maize store–time and household head marital status. In the Northern Zone of Tanzania, maize is the main crop produced by majority of the households and hence standing as the most produced staple food in terms of volume and second cash earning crop. With this regards, inner grain storage motive ensures income security to the community. This fact is in line with Miller and Hayenga (2001) who also confirmed that maize contributes to per capita energy consumption and incomes, especially in the developing countries. Thus modeling of its storage structure with their respective store–time is of high importance so as to attain its equilibrium price.

The average value of livestock was found to be high in this study. Majority of the household in the study area had both crop and livestock as their main economic activities. The highest value attached to the livestock implied high purchasing power of storage facilities. It was obviously observed that there is an association between wealth and application of insecticides as one of storage method. Such observations were in agreement with Boughton *et al.* (2007) who reported similar findings that there is a high correlation between wealth of an individual and value of assets he/she is possessing, and purchasing power, thus wealth households were in a good position of using improved storage structures than poor households.

Major social services were close to most household within a range of 2.8 km to 7.7 km which ensured their accessibility. Following Gebremedhin and Hoekstra (2007) line of thinking, an individual's accessibility to extension services was definitely linked to an increase in the adoption rate in improved agricultural technologies. The strong empirical proof exists that shorter travel distances to markets increased the probability of adopting the yield-rising technologies (Diao *et al.*, 2008). Furthermore, access to social services enhances professional and social interactions among farmers which speedup technology adoption. Taking education level as a major factor toward technology adoption, there were slight variations in education level with regards to gender, females with no education exceed males by 4%, and females with post-secondary education were 2% less compared with males. As declared by Feder and Slade (1984) that, educated farmers are assumed to be early adopters of new technology and are expected to be more knowledgeable of advanced farming systems.

PICS bag scored the least coefficient of correlation which implied a negative associations between storage structure and insect damaged kernels i.e. the more grains stored under PICS bag the less insects damaged kernels. Similar results have been observed from the descriptive statistics, whereby PICS bag was found to be the best in minimizing insect damaged kernels with least contributions. The observed results are in line with Hell *et al.* (2010) who reported that that, PICS bags can preserve maize grain with less than 0.5% dry weight losses over a six month storage period in field tests without the use of chemicals. These results are highly associated with its building design which allows no oxygen circulation, thus there will be neither growth nor development of insect pest invaded grain in the field and on storage. A reported by William *et al.* (2017) indicated that the triple plastic linings inside PICS bag

significantly hamper oxygen movement within the stored grain resulting in a negative response on the insect survival rate.

Using the generated multivariate linear regression model the results should that maize grains can be stored in the PICS bags for six months consecutive with minimum insect damaged. These results confer with Bauoa *et al.* (2012) that, PICS bags secure maize grains against storage insect pests with no insect damaged kernels throughout six months consecutively. Hence, PICS bags can be regarded as one of the improved storage structures to be used in maize storage to minimize postharvest losses for improved food security. In order to stimulate PICS bag adoption rate, there should be deliberate measures from all necessary stakeholders to ensure its accessibility and availability with affordable price contrary to the prevailing one i.e. 5000 Tsh/unit which seems to be expensive.

Metal drum were ranked second storage structure in minimizing insect damaged kernels. Such results indicated an inverse association between postharvest losses and maize grain storage under Metal drum. A similar result was observed from descriptive statistics accounting about 4% of the insect damaged kernels. The results are similar to De Groote *et al.* (2013) which demonstrated that metal silos (Metal drum) were found to be effective in preventing stored maize against the larger grain borer and maize weevils with no any pesticides applications. Furthermore, Metal drum in this study proved to be effective in minimizing insect damaged kernels throughout six months store–time. The Metal silos (Metal drums) are effective in controlling maize weevils and the larger grain borer without the use of pesticides for at least four months during storage under conventional storage systems (De Groote *et al.*, 2013; Teferra *et al.*, 2012). Despite the efficiency observed under metal silo, its adoption involves some challenges such as; high initial investment cost and large storage space for the large storage volume (Thamanga–Chitja *et al.*, 2004).

Polyethylene bags with insecticide were found to the second dominant storage methods in the Northern Zone of Tanzania. The insecticides preferred by most farmers were Actellic dust and Shumba. Similar to the findings of this study Kadjo *et al.* (2013) reported that the common insecticide used by 23% of the respondents in maize was Actellic dust. The high response of households toward Polyethylene bags with insecticide as their main storage structure might be highly associated with low cost and regular contact between farmers and extension services as a source of information (considering shorter distance averaging 3.2 km.

Similar to the findings of this study Maboudou *et al.* (2018) asserted in his study that, availability of the insecticides and the applications knowledge fastens adoption. On top of that, Pimentel and Levitan (1986) reported that, the growing trend in the applications of pesticides is highly influenced by its gradual prices increase with a comparison to other agricultural inputs.

This study has also shown that Polyethylene bags with insecticide have significant contributions on maize postharvest losses. Similar results were observed from the correlation matrix with a coefficient of correlation 0.037 which implied that there is an increase of 0.037 units of postharvest losses in the cause of store grains under Polyethylene bags with insecticide as per support by Contrarily to Mutambuki *et al.* (2012). Therefore, the effectiveness of insecticide depends highly on the infestation level. Ofori *et al.* (1998) documented that, Actellic super dust are efficient in almost three months store-time in low infestation zones. Hence, the insecticide inefficiency observed from the result might be highly associated high infestation zone of the studied area, ignorance of farmers on insecticide application i.e. proper dosage, observing expiring dates, timing and presence of counterfeit insecticide.

Polythene bags without insecticide were found to be the dominant storage structure employed in the study area despite its significant contributions in postharvest losses amounting 43%. These findings are similar to Udoh *et al.* (2000) who found that Polythene bags without insecticide was the most common maize storage structure/method found in almost many maize growing locations. Furthermore, there was a strong correlation between store-time and insect damaged kernels and such observations indicated an increase in maize postharvest losses. Thamanga-Chitja *et al.* (2004) reported a similar result that, Polyethylene bags without insecticide offers tiny defense alongside storage insect pests especially borers in only a short time interval. The observed inefficient is highly associated with Polyethylene bag building materials which are weak in maize grains protection against insects especially borers, also the possibilities of the stored grains to absorb moisture from the floor in case of direct contact resulting into maize rotting.

In this study, the traditional storage structure *Kihenge* experienced significant insect damaged kernels more than other storage methods. Similar trends of results were observed also in this study from a correlation matrix showing that, there were a significant number of insect-

damaged kernels in *Kihenge* which also implied that there was a significant association between postharvest losses and grain stored under *Kihenge*, whereby the more grains stored under *Kihenge* the more loss will be experienced. As of these results, there was no suggested store–time under *Kihenge* and this was highly associated with fewer numbers of observations for *Kihenge* study. Basically, *Kihenge* was adopted with only 1% of the total respondents from the baseline survey.

The World Bank (2011) also found that the traditional mud granaries (*Kihenge*) are being abandoned due to lack of knowledge on how to construct them, lack of space as they take up a lot of room even when empty compared with sacks, lack of ability to move them rapidly in case of fire or flood and less easy to market the stored grain rapidly. Thamaga–Chitja *et al.* (2004) also reported inefficiencies of the Mud and twig (*kihenge*) to be associated with lot of holes in its structure which allows rodent and other insect pest access to the stored maize leading into maize losses and grain quality and safety deteriorations. Cracks/holes inside this structure could have acted as residence for most insect pests (Mhlanga, 2010). Considering its building materials (mud and plant materials), the structure can be easily broken down resulting in maximum airflow as essential element attracting insect pests in storage.

Moisture content in stored grains is an important component in grain physical value. The storage structures are considered to be efficient if moisture can be maintained to the optimum levels throughout the storage time (Cuevas *et al.*, 2016). In this study, the multivariate linear regressions were generated to evaluate the interaction between storage moisture content trends and insect damaged kernels in the PICS bag, *Kihenge*, Metal drum, Polyethylene bags with insecticide and Polyethylene bags without insecticide. From the results, there were no significant variations in moisture content trends throughout six months store–time in other four storage structure except Metal drum with *P*–value 0.01 and coefficient of 0.04 indicating that there was a positive relationship between moisture content trend and store–time under this structure, whereby an increase in unit store–time resulting in an increase in maize grains moisture content by 0.04 units.

The results can be highly associated with the improper sealing of Metal drum lids and/or building materials as reported during focused group discussions. Similar scenario has been documented by Yusuf and He (2011) that, for perfect metal silo protection against rodent and insects pest attacks on the stored grains, airtight sealing is very crucial. Following the same

line of thinking, Thamaga–Chitja *et al.* (2004) in a research conducted in Northern Kwazulu–Natal reported that sampled respondents were tightly sealed the lids of the tanks with cow dung as remedies against maize rot in the cause of tanks sweating. Thus the effectiveness of the structure is highly recommended in the moderate temperature zone following proper grain drying chains.

Basically, selection of storage structure is highly influenced by the storage cost of the specified structure throughout the store–time as shown in a correlation test during this study. Polyethylene bag without insecticide had a strong coefficient of correlation which shows a positive strong association between storage structure and the storage cost. This conclusion is in line with Udoh *et al.* (2000) who reported that, farmers are not ready to bear extra cost in the cause of insecticide application. This study has indicated a strong link between store–time and PICS bag. The results are in line with Baoua (2014) who found that grain held in PICS bags for six month store time were found to have neither weight losses nor grain damage.

This study also showed that there is a significant difference on maize store–time among households basing on the quantity of maize harvested by the household. Using a generated multivariate regression model, a household can optimize their return to investment from five-month store–time with a highest coefficient. In order to maximize household returns to investment as a function of store–time, storage cost, production cost, maize sales on November, and March and maize sales on April are variables with very high significant contributions on household income maximization. Therefore, a slight change in the fore mentioned variables may result in very significant alterations on household income; hence need to be given special attention. However, maize sales on December and maize selling price on January and marketing cost have significant contributions on household income hence a change in these variables reflect a change in household income.

In northern zone of Tanzania, maize marketing channels begins with a large and highly distinguished set of farmers over an equally various group of key assemblers and transporters before reaching other marketing channels actors and finally consumers with an inclusions of exchanges between farmers and consumers as well as small and medium-sized traders to small retailers and consumers. Large amount of maize grains pass through the marketing scheme in the absence of large trading and processing firms. As such, there are many different transaction points within the value chain, many of which overlap and feed into one

another until maize reaches to the final consumer whereby most of them are farmers who sold their produces soon after harvest (Fig. 7).

This study found that, maize middlemen (village grain assemblers) stand as main farmer's market sources and hence affect the interaction between households and urban traders. In this context, the middle man plays a key role in marketing of maize due to high transaction cost in the cause of poor rural transportation infrastructures, and at times the village middlemen in some cases they provide financial assistance to farmers (as reported during Focus Group Discussion). Also majority of smallholder's farmers located in remote areas depend highly on village middlemen/brokers (Kherallah and Kirsten, 2001; Makhura, 2001).

In additionally, Mmbando *et al.* (2006) reported that, rises in marketing costs as a result of poorer road infrastructures to the distance market encourages farm gate sales. Despite the identified price differences between farm-gate price (home selling price) and the higher market prices yet, farmers depend highly on middlemen as a direct source of the market. Chirwa (2009) in a similar study conducted in Malawi found that farmers in the central region were more likely to sell their maize grains to private traders rather than local markets. Also, Jayne *et al.* (2010) in their study documented that, local/village maize assemblers are the main marketing route for smallholder farmers in their study areas. Ignoring the fact that, choices of marketing channel have a direct impact on the household income in the end because marketing cost varies based on marketing channels which differentiate household returns to investment.

This conclusion is being guided with a simple linear regression output which shows that, there is a significant variation of household income based on the choice of their marketing channels. Sitko and Jayne (2014) reported similar findings that in Zambia farmers who sell their maize directly to grain processors receive an average of \$US.08/kg more than those that sell to assembly traders in the village. Furthermore, 52% of the respondents depend highly on the middlemen as a source of price information, the rest 48% depends on their neighbours. Due to the fact that the majority of farmers lack market information i.e. who are buyers, where to find them, when and how. Azam *et al.* (2012) drew similar conclusions that smallholders farmers don't have access to the market information including; selling prices, who are consumers, customer taste and preferences, market location, when to sell, competitive market environments and all necessary legislative issues. Basically, accessibility

to maize market price information would have a direct impact in rising farmers bargaining power with intermediaries and household income as well. The contributions of maize marketing channels need to be well modelled considering its significant relationship with household income and return to investments.

Monthly maize price trends on the studied area for two cropping seasons consecutively have been collected to justify maize store time for each season. Results show that there are price differences between two cropping seasons. The 2016/17 season was found to be higher compared with 2017/18. Despite the economic theory assumptions that with an increase in commodities price large quantities will be offered to the market, yet, these results showed that there is no significant relationship between the quantity of maize sold in the household and the accessibility to price trends information. Hence, the quantity of maize sold by the households is driven by other factors rather than market prices. A study conducted in Zambia by Mather *et al.* (2013) reported similar findings that, the majority of the surveyed households were found to have little/no positive responsiveness of maize market contribution to higher predictable maize prices. Additionally, Mathur and Ezekiel (1961) and Enke (1963) documented similar findings that farmers' planting and marketing decisions are mostly driven by customary conduct and practices rather than price.

Nevertheless, most of the farmer's usually sale large volume of their maize stock soon after harvest with low prices, ignoring the fact that maize prices rise just few months after harvest to the point that smaller quantity of maize sales brings much cash. The situation is highly influenced by their desperation to cater for social obligations. Furthermore, during Focus Group Discussion farmer claims to have no power to dictate maize price. They were simply accepting prices given by village traders/assemblers. Mvula *et al.* (2003) in their study documented similar findings in which maize traders dominated the maize prices in the market. The local maize assemblers were the main marketing option for smallholder farmers in all the sites visited during the study.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study revealed that, household can optimize income generated from maize investment for at least six months store-time. Therefore, maize store-time as a major aspect of Post-Harvest Loss need to be given much attention. Farmers should be well equipped with all necessary techniques on improving their store-time with the aim of gaining much profit taking advantage of price variability. This is based on the fact that, farmers opt for immediately postharvest sales despite its low price in order to meet their social obligations. In this study, PICS bag proved to be the most efficient improved storage structure/method with least contributions to maize postharvest losses throughout six months store-time, although it wasn't a dominant storage structure within a study area compared with polyethylene bags. In additionally, metal drums were found to be the second best storage structure throughout six months store-time when farmers followed proper maize drying chain before storage.

5.2. Recommendations

This study recommends that farmers can use PICS bag for maize storage up to six months. However, more research is needed to expose maize grain for longer periods of time i.e. more than six month and evaluate whether or not the PICS bag can still be used with good results. Improved maize storage structures should be purchased in advance prior to harvesting to accommodate proper store-time basing on the fact that small-scale farmers undergo cyclical income flows. Provision of an improved storage structures should be regarded among other agricultural inputs to be carried out under an input subsidy scheme to boost its adoption rate. Alternatively, the Government and other stakeholders should develop a financial scheme to enable farmer's accessibility to the improved structure at affordable prices. Advisably, more studies should be done on the prevailing maize grains drying chain apart from sun drying, to evaluate their efficiencies and intervention measures, considering the contributions of storage moisture content on grain quantity and quality losses. Finally, this study recommends not more than seven month store-time for household income optimization.

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APPENDICES

Appendix 1: Survey Data Collection Tool

SECTION 1: DEMOGRAPHIC INFORMATION

1. How many household members are ≥ 15 years old?
2. How many household members are ages 10-14?
3. How many household members are below age 10?

Household characteristics

Name	Age	Sex <i>1=male 2=female</i>	Relationship to current head <i>See codes below</i>	Marital status <i>See codes below</i>	What is the highest level of education completed? <i>See codes below</i>	How many months in the period May 2016 to April 2017 has this person been living at home?	Did this person receive cash from informal/ business activity Between May 2016 & April 2017? <i>1=yes 2=no</i>	If yes, monthly income estimate (TSh) for the months in which informal income was earned (net value)
name	dem1	dem2	dem3	dem4	dem6	dem7	dem8	dem9

4. Did this person receive cash or payment in kind from wage or salaried employment (including labor)? *1=yes, 2=no*
5. If YES, monthly income estimate (*Tsh*)
6. Hours spent working in average week?

SECTION 2: CROP PRODUCTION

7. Did this household have any cropping activity during 2017/2018? (*1= yes, no=2*)
8. Was this your plot intercropped? 1= yes, 2= no
9. If yes, how many crops are in this plot in total?
10. How big is your farm?
11. Have you finished harvesting? 1= yes, 2= no
12. If no, estimate your total harvest (kg)

SECTION 3: CROP SALES

13. Did you sell any crops in 2017/18? *1=yes 2=no*
- Crop sales from the previous year (2016/17) harvest

Crop produced in 2016/17 agricultural year	Quantity harvested		Quantity sold		Price per unit at largest sale (TSh)
	Amount	Unit	Amount	Unit	

SECTION 4: SOCIAL CAPITAL

14. Is there a member of the household who is a member of any group? 1=yes; 2=no;

15. If yes, who is that? (Refer household ID in demographic table)

16. Major group activities (up to 3, beginning with the group most important to your household)

SECTION 5: LIVESTOCK

17. Did you have any livestock in the period past 12 months *1=yes, 2=no,*

	Livestock code	Number owned April 2018 [Include livestock kept by others]	Current average value (Tsh)	Number sold	Average unit price when sold (Tsh)
Local cow	1				
Local bull	2				
Local calves	3				
Improved cow	4				
Improved bull	5				
Improved calves	6				
Sheep	7				
Goat (local)	8				
Goat (dairy)	9				
Pig	10				
Chicken-local	11				
Chicken-improved	12				
Duck / Geese	13				
Rabbit	15				

SECTION 6: HOUSEHOLD ASSETS (PROMPT for each item as listed below)

At present, how many of the following does this household own that are usable/repairable?
For value per unit, ask for the current purchase price of the asset as is, or the current market value of the asset as is.

		Number Owned May 2017/18	Average value per unit (TSh)
asset	asset name	qty	value
	Transport		
1	Car/Truck		
2	Motorcycle		
3	Tricycle		
4	Bicycle		
6	Tractor		
7	Trailer		
	Farm		
8	Hoes		
9	Spades/shovel		
10	Ploughs		
11	Sprayer pump		
12	Water pump		
13	Water tank		
14	Water trough		
15	Irrigation equip.		
16	Wheelbarrow		
17	Storage		
18	Poultry houses		
19	Piggery houses		

		Number Owned May 2017	Average value per unit (TSh)
asset	asset name	qty	value
26	Sheller		
27	Combine harvester		
28	Generator		
29	Power saw		
30	Grinder		
31	Cane crusher		
32	Cart		
33	Hammer mill		
34	Weighing machine		
35	Beehive		
36	Incubator		
37	Fodder cutter		
	Household		
40	Houses (residential)		
41	TV		
42	Radio		
43	Mobile phone (dumb)		
44	Mobile phone (smart)		
45	Solar panels		
46	Battery		

SECTION 7: INFRASTRUCTURE

Distance should be recorded in kilometers (km).

What is the distance from your homestead to extension advice/service?	
What is the distance from your homestead to the nearest market place for farm produce?	
What is the distance from your homestead to the nearest livestock market place? (-99= <i>don't know</i>)	
What is the distance from your homestead to the district headquarters?	
What is the distance from your homestead to a motor able road?	
What is the distance from your homestead to a tarmac road?	
What is the distance to the nearest piped water source?	
What is the distance to the nearest health centre?	
What is the distance to the nearest electricity supply?	
What is the distance to the nearest phone reception?	
What is the distance from your homestead to the nearest fertilizer seller?	
How much does it cost to transport a 50-kilo bag of fertilizer from the nearest seller to homestead? (TSh)	
With what type of transport from seller to homestead? 1= <i>car</i> , 2= <i>bus/daladala</i> , 3= <i>bicycle</i> , 4= <i>motorcycle</i> , 5= <i>ox cart</i> , 6= <i>donkey</i> , 7= <i>tractor</i> , 8= <i>other</i> , specify____	
What is the distance from your homestead to the nearest seller of hybrid maize seed?	
What is the distance to the nearest town where you can sell your crops?	
How much does it cost to transport one 100-kilo bag of maize to the nearest district headquarters? (TSh)	
With what type of transport from your homestead to the nearest town? 1= <i>car</i> , 2= <i>bus/daladala</i> , 3= <i>bicycle</i> , 4= <i>motorcycle</i> , 5= <i>ox cart</i> , 6= <i>donkey</i> , 7= <i>tractor</i> , 8= <i>other</i> , specify____	

SECTION 8: OTHER INCOME

18. Estimated household income from other sources

19. Indicate the estimated household income from other sources for the past 12 months (include in-kind receipts to the household)

Garden sales	Did you receive income from this source? 1= <i>yes</i> , 2= <i>no</i>	Monthly income (TSh)	Number of months income was received
Remittances			

Rental income (Land)			
Rental income (Buildings)			
Income from business			
Donations/gifts			
Other (specify)			

SECTION 9: FOOD SECURITY

Months of Adequate Household Food Provisioning

		1=yes, 2=no
In the last 12 months, were there any months when your household did not have enough food to meet the household's food needs?		
If yes, please indicate during which months your household did not have enough food to meet the household's needs	April 2018	
	March 2018	
	February 2018	
	January 2018	
	December 2017	
	November 2017	
	October 2017	
	September 2017	
	August 2017	
	July 2017	
	June 2017	
	June 2017	
	May 2017	

SECTION 10: STORAGE

20. What storage methods does this household use for storing maize after harvesting?
21. How much did the household spend on insecticides for local storage? Tsh
22. Have you ever used PICS bags to store maize? Yes/No
23. If 19.3=no, why not?
 - 1=High price;
 - 2=Low storage capacity;
 - 3=No major storage losses from insects;
 - 4= Not aware of hermetic bags;
 - 5=Other
24. Are PICS bags available in this area? Yes/No
25. If yes, what is the price per bag?

SECTION 11: PRICES

26. At the nearest local market, what was the buying price for maize in May 2017?
27. At the nearest local market, what was the buying price for maize in December 2018?

END

RESEARCH OUTPUT

Output 1: A research paper titled “Integrating Storage Structures and Store-Time in Maize Grain Postharvest Losses Evaluation in Northern Zone of Tanzania”



International Network for Natural Sciences (INNspUB)

E- 929, Kadirgonj, G.P.O. 6000, Boalia,

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Dear Author,

Your paper entitled “Integrating Storage Structures and Store Time in Maize Grains Postharvest Losses Evaluation in Northern Zone of Tanzania” has been accepted to the International Journal of Biosciences (IJB) and payment for further processing of the paper is requested. Thanks for your contribution.
