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ECONOMICS OF HERMETIC STORAGE TECHNIQUE: THE CASE OF MAIZE GROWERS IN WEST GOJJAM ZONE, AMHARA NATIONAL REGIONAL STATE, ETHIOPIA

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COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

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ECONOMICS OF HERMETIC STORAGE TECHNIQUE: THE CASE OF MAIZE GROWERS IN WEST GOJJAM ZONE, AMHARA NATIONAL REGIONAL STATE, ETHIOPIA

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APPROVAL SHEET

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BAHIR DAR UNIVERSITY

As Thesis research advisors, we hereby certify that we have read and evaluated this Thesis prepared under our guidance, by Gashaw Tenna Alemu, entitled, ECONOMICS OF HERMETIC STORAGE TECHNIQUE: THE CASE OF MAIZE GROWERS IN WEST GOJJAM ZONE, AMHARA NATION AL REGIONAL STATE, ETHIOPIA, we recommend that it be submitted as fulfilling the Thesis requirement.

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As member of the Board of Examiners of the MSc Thesis Open Defence Examination, we certify that we have read, evaluated the thesis prepared by Gashaw Tenna Alemu and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the degree of Master Science in Agriculture (Agricultural Economics).

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Final approval and acceptance of the Thesis is contingent upon the submission of the final copy to the Department Graduate Council (DGC) through the College of Agriculture and Environmental Sciences of the candidate€s major college.

DECLARATION

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DEDICATION

To my lovely brothers, Wondwossen Tenna Alemu and Le€alem Tenna Alemu who had been passed away without getting any education opportunities at their infa stage

LIST OF ABBREVIATIONS

ANRS	Amhara National Regional State
ASSP	Agriculture Service Support Programme
asl	Above Sea Level
BWoA	Bure Woreda Office of Agriculture
CSA	Central Statistical Agency
DAs	Development Agents
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization
FGDs	Focus Group Discussion
FHHs	Female Headed Households
GM	Gross Margin
GOs	Government Organizations
GDs	Group Discussions
GP	Gross Profit
GTZ	German Agency for Technical Cooperation
HHs	Household Heads
HS	Hermetic Storage
IFPRI	International Food Policy Research Institute
KI	Key Informant
KII	Key Informant Interviews
LGB	Larger Grain Borer
MA	Marginal Analysis
ME	Marginal Effect
MHHs	Male Headed Households
MoA	Ministry of Agriculture
MRR	Marginal Rate of Return
MVP	Multi Variate Probit
NGOs	Non-Governmental Organizations
NS	No Storage

PB	Partial Budget
PHL	Post-Harvest Loss
PICS	Purdue Improved Crop Storage
PKAs	Peasant Kebele Administrations
PU	Purdue University
Qt	Quintal
RoI	Return on Investment
SSA	Sub-Saharan Africa
SSI	Semi Structured Interview
TAC	Total Additional Cost
TAI	Total Additional Income
TLU	Tropical Livestock Unit
TRC	Total Reduced Cost
TRI	Total Reduced Income
TSP	Traditional Storage with Pesticide
TVC	Total Variable Cost
TV	Television
UKA	Urban Kebele Administration
USAID	United States Agency for International Development
USD	United States Dollar
WGZDA	West Gojjam Zone Department of Agriculture
WTP	Willingness to Pay
WWoA	Womberma Woreda Office of Agriculture

ABSTRACT

Post-harvest loss of the food product is significant given the lower total agricultural productivity in Sub-Saharan Africa. Although the maize production potential in Ethiopia, especially in West Gojjam zone, is estimated to be high, substantial storage loss and lower profit could happen due to the lack of using modern storage techniques. Thus, there is a high demand to use modern storage technique like hermetic storage or Purdue Improved Crop Storage (PICS). However, the economic costs and benefits are not well studied yet, which prevents the widespread use of the technique. Therefore, this study ascertained to analyze the economics of hermetic and other maize storage techniques and analyzing the determinants of use of maize storage techniques in Bure and Womberma Woredas of West Gojjam Zone, Ethiopia. A multi-stage random sampling technique was used to select 450 household heads (HHs) to collect a cross-sectional data through structured interview schedule in 2017. Besides, focus group discussions and key informant interviews were held. The gross margin (GM), partial budgeting, marginal analysis, descriptive, and inferential statistics were used to analyze the data. Moreover, multivariate probit regression model was used to analyze the determinants of use of maize storage techniques. Most farmers (87.8%) used traditional storage with pesticide (TSP) while 66.7% and 19.6% used PICS and no storage or selling immediately (NS), respectively. The PICS was the most profitable, with GM of 498.95 ETB Qt^{-1}, the highest difference in GM (134.67 ETB Qt^{-1}) and highest marginal rate of return (MRR) (6.657) ratio were observed when the storage technique changed from NS to PICS. The increment of experiences in cooperatives and perceptions on the higher PICS price determined HHs decision to sell the maize products immediately, whereas, age and non-food items expenditure influences HHs decision to use TSP positively. Literate HHs, higher farming experience, earlier cooperative membership trend, more livestock holding size and annual crop income, better access to extension information about PICS, and positively perceiving the higher PICS storage capacity probably increased the use of PICS; whereas the higher amount of own land holding size and non-food items expenditure, other agricultural inputs demand and the lowest perceived status that PICS has higher price negatively affected farmers to use PICS. Finally, wider promotion and utilization of PICS is highly recommended to reduce storage loss and increase profit in the study area, which can be achieved by optimizing the current initial investment cost, diversified use of media for diffusing extension information about PICS, provision of PICS credit, providing PICS which have larger storage capacity, and assisting farmers to establish maize producer and marketing cooperatives so as to store large quantity in groups

Keywords: Storage Techniques, PICS, Maize, Gross Margin, Marginal Rate of Return, Factors Affecting, Multivariate Probit

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1. INTRODUCTION

1.1. Background of the Study

Across Sub-Saharan Africa (SSA), staple grain crops provide the foundation for household food security through both income generation and direct consumption by small farming households by producing more than 112 million tons of grain year^{-1}, and the grain sub-sector accounts for approximately 37% of incomes (World Bank, 2011). However, SSA agricultural per capita returns are too low in the world (African Union, 2006). Additionally, a significant post-harvest loss (PHL) was recorded (World Bank, 2011).

Storage is a pathway for reducing major PHL for most cereals including maize in developing countries, which are produced on a seasonal basis that harvest a year, which itself may be subject to failure (FAO, 1994). Moreover, it is a process by which agricultural products are kept for future use, and it is an interim and repeated phase during transit of agricultural produce from producers to processors and its products from processors to consumers (Thamaga-Chitja et al., 2004). As a result, the stored crop would gradually release to the market during off-season periods, which also stabilizes seasonal prices (Adejumo & Raji, 2007). Therefore, the time-based storage of grains is critical for household food security in terms of food supply and seed availability for small-scale farmers (Adetunji, 2007). The most commonly used storage types in developing countries include traditional such as granaries, underground storage, clay pots, etc., semi-modern, and improved such as hermetic technologies, of which the first and the second aforementioned methods are the most common (Adesuyi et al., 1980; Udoh et al., 2000).

Maize (Zea mays L.) is the highest prioritized cereal crops cultivated for human foodstuff and animal feed. Total maize annual production and productivity exceed all other cereal crops (CSA, 2013). Despite its importance, i.e. least expensive cereal to produce ha^{-1} and a high source of calorie with minimum expense, significant storage loss (15-40%) exhibited and marketing takes place immediately after harvesting due to economic problems (African Union, 2010). The study areas, Womberma and Bure Woredas[e], are the leading maize producer areas in West Gojjam Zone[f] in particular and Amhara National Regional State (ANRS) in general. Farmers who cultivated maize in the study areas use different storage techniques such as traditional structures and hermetic storage (HS), i.e. Purdue Improved Crop Storage (PICS) technology (ANRSBoA, 2016). A PICS bag which is made up of a triple-layer airtight plastic have so many advantages, i.e. can be easily handled, have two-year shelf life unlike the regular bags which are often used for only one production season, and significantly hamper the oxygen circulation so that it prevents insects from accessing the required oxygen and hence their growth would be hindered (Purdue University, 2014). However, the economic costs and returns implications for farmers are unknown.

1.2. Statement of the Problem

The major cones of typical African traditional storage technique which usually practiced in Ethiopia have exposed the stored product to pest attack since it had a single hole for loading and removing grains, and have conducive conditions for reproduction for storage pests (Murdock et al., 2003). Moreover, the techniques are not air tighten that easily destroyed by pests and advanced other infestation (Ngamo, 2000; Adejumo & Raji, 2007). As a result, the extent of smallholder farmers pesticide usage for stored grains are abundant in Ethiopia (70%) (Abraham & Firdissa, 1991), Benin (50%) (Hell et al., 2000), Cameroon (23%) (Nukenine et al., 2002) and Eritrea (12%) (Haile, 2006). Moreover, they often misuse chemicals resulting in health and environmental problems (Baributsa et al., 2010). Additionally, the socio-economic impacts of using synthetic chemicals are environmental pollution, health deterioration, loss of means of living, changes in costs of living, child labour abuses, etc. (Zvonko et al., 2015)

Smallholder farmers in SSA including Ethiopia face numerous challenges after their maize grain leaves the field due to the significant quantity losses by insect pests damage (Kadjo et al., 2016) particularly by larger grain borer (LGB), Prostephanus truncates (Horn) (Coleoptera: Bostrichidae) and the maize weevil Sitophilus zeamais Motschulsky (Coleoptera:

[e] District
[f] Province

Curculionidae) (Vowotor et al., 2005). Moreover, lower quality grain due to insect attack and high moisture could significantly affect household food security, income, and market prices fluctuation. To illustrate specifically, maize sold at 160 ETB Qt^{-1} [§] (0.084 USD Kg^{-1}) after harvest in February to March and can realize 300 ETB Qt^{-1} (0.158 USD Kg^{-1}) in the period of August to October (IFPRI, 2011).

Another problem of the most predominant storage structures practiced in SSA are blamed to have the least gross margin (GM), i.e. least profitable. According to a survey result conducted in Nigeria, the crib, i.e. modern storage technique, was the most profitable maize storage system with a profit of 83,813 N[**] ton^{-1}, while elevated barn structure (traditional storage) was the least profitable with 37,200 N ton^{-1} (Adefemi, 2016). Likewise, in another survey study result conducted in the same country, the cost and return analysis proofs that modern storage techniques used is the most profitable with GM of 12,435 N ton^{-1}, highest difference in GM (8135 N ton^{-1}), and highest marginal rate of return (MRR) (1.10) (Adetunji, 2007). Moreover, the GM for maize growers using various storage technologies are; 4,300 N ton^{-1} (no storage), 8,345 N ton^{-1} (local), 11,135 N ton^{-1} (semi-modern) and 12,435 N ton^{-1} (modern) (Sekumade & Oluwatayo, 2009). Also selling immediately is not as financially viable as selling after storing. This significant gross income difference loss occurs that many farmers lack access to effective and safe storage technology, such as airtight storage bags or metal silos (Jones et al., 2011; Zachary et al., 2015). Though these technologies have costs and return implications on household income and the potential to impact household food security and welfare, it is not scientifically studied in many rural settings of Ethiopia. Hence, a systematic study of the economics of each storage technique would be vibrant to select the most viable technology from farmers€ perspective.

Effective storage techniques allow smallholder farmers to gain more benefit through selling maize when the market price is relatively high. Nevertheless, on the prevailing local storage practices, the short-term and inter-seasonal market price fluctuation is common that negatively influenced producers€ and consumers€ interests. On this regard, the indigenous storage

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§ 1 Qt = 100 Kg

** Nigerian Official Money

techniques with pesticide application are native and basic; some have been found to be functional, needing just little improvements while others are dated and hazardous (Thamaga Chitja et al., 2004). A major problem of agricultural development in Ethiopia has been lack of modern and appropriate storage technologies for grains. Most new improved technological innovation packages are improperly set up and also very expensive for smallholder farmers. In light of these, there exist a problem of appropriate modern storage and maize wastage in Ethiopia in general and ANRS in particular, despite the highest potential of maize productivity.

All of those aforementioned storage and wastage challenges undermine household income, food, and nutrition security, food safety, health etc. in the study area. Therefore, assisting smallholder farmers through promoting storage technologies that are effective, affordable and safe for humans and the environment are critical particularly in the study areas (ANRSBoA, 2016). Thus, it urges the need for economical storage techniques for poor people in the study area today more than ever. Because farmers are subsistence which is low economic means, who suffer the most from post-harvest insect pests and resulting losses of food and monetary value. Therefore, any storage technique they use have to be efficient, effective, low-cost, not need the extra use of insecticides, not easily damaged by rodents, available in local markets, easy to learn, culturally acceptable, ecologically sound, etc. To do so, a systematic study that thoroughly quantifies the economic costs and returns of maize storage techniques plus the determinants of smallholder farmers€ decision to use the existing storage techniques was scanty.

1.3. Objective of the Study

1.3.1. General objective

The general objective of the study is to analyze the economics of HS (PICS) and other techniques on maize growers in West Gojjam Zone, ANRS, Ethiopia.

1.3.2. Specific objectives

- analyze the economic costs and returns of HS and other techniques;

- analyze the determinants of farmers€ use of maize storage techniques

1.4. Research Questions

- What are the economic costs and returns of HS and other techniques to farmers?
- How different factors affecting farmers€ decision to use maize storage techniques?

1.5. Significance of the Study

The research results focused the economics of hermetic maize storage and other techniques help to select and implement the most viable technique in terms of financial feasibility. In the meantime, it would be a benchmark for the scaling up of effective and efficient storage techniques since a rational decision making about storage techniques require consistent evaluations of the financial viability of each storage technique. Knowledge of these economic values is indispensable for making investment decisions concerning storage techniques advancement, policy briefs and choices on sustainable PHL reduction structure, etc.

The information generated from this research could be used by the government organizations (GOs) and Non-governmental organizations (NGOs) to carry out grain storage related projects. The knowledge generated from analysis of factors that influence farmers€ use of maize storage techniques can help policy makers to design PHL reduction programs. Furthermore, it can serve as a benchmark and a source of information for other researches which would be conducted in the study area on PHL reduction techniques and related topics.

1.6. Scope and Limitations of the Study

The objective of the study was to analyze the economics of HS and other techniques in general, analyze the costs and returns implications of HS and other maize storage techniques and analyze the determinants of farmers€ use of maize storage techniques at household level in West Gojjam Zone, ANRS, Ethiopia.

The concept of the economics of hermetic maize storage techniques is a very broad concept since it should include demand, supply, distribution, production, etc. However, the scope of the study is more focused but not limited to the analysis of demand side of HS techniques from a cross sectional data at a given point in time. Besides, the sample used for this study is restricted in both coverage and size due to limited time and finance, i.e., confined in two Woredas, six Peasant Kebele Administrations (PKAs) and 150 household heads (HHs) sample size so as to make the work manageable, feasible, applicable and to set it precisely. Hence, the study did not cover the entire rural population in the area, including both male headed households (MHHs) and female headed households (FHHs).

1.7. Organization of the Thesis

In the proceeding section, chapter two depicts literature reviews and the model of theoretical framework. In chapter three, research methodology is discussed with reference to describing the study area, sampling design, sources and methods of data collection, and data analysis. Meanwhile in chapter four; the findings of the research are descriptively interpreted to see the economic costs and returns of maize storage techniques, factors affecting farmers€ decision to use maize storage techniques, and opportunities and challenges of maize storage techniques with particular attention to HS technique. Moreover, in spite of the descriptive findings, the econometric model result was analyzed to see the extent how different factors affecting farmers€ decision to use maize storage techniques. Chapter five, the conclusions and recommendations are put forth.

2. LITERATURE REVIEW

2.1. Descriptions of Maize Production in Ethiopia

The second most extensively cultivated crop in Ethiopia, maize, could be grown up in different climatic and socio-economic conditions, particularly in six major clusters; moist and semi-moist mid-altitudes (1700–2000 m asl, 1000–1200 mm rainfall), moist upper mid-altitudes (2000–2400 m asl; >1200 mm), dry mid-altitudes (1000–1600 m asl; 650–900 mm), moist lower mid-altitudes (900–1500 m asl; 900–1200 mm), moist lowlands (<900 m asl, 900–1200 mm), and dry lowlands (<1000 m asl, <700 mm). The moist and semi-moist mid-altitude Zones comprise the bulk of the national maize area in Ethiopia, which covers about 75% of the national maize production area whereas the dry ecologies cover the remaining 25%. Smallholder farms account for more than 95% of the total maize area and production in Ethiopia. The farmers use animal traction for land preparation and cultivation; almost all production is rainfed, irrigated areas accounting for only about 1% of the total (MoA, 2005).

The top five maize producing Zones of Ethiopia are West Gojjam, Jimma, East Wellega, West Wellega and East Gojjam. Most of these fall in the mid-altitude (1500–2000 m asl) range (CSA, 2011). More than 9 million households, more than for any other crop, grow maize in Ethiopia. The annual rate of growth for the number of households cultivating maize grew at 3.5% each year between 2004 and 2013, compared to 3.0% for Sorghum, 3.1% for Teff, 2.1% for Wheat, and 1.9% for Barley. At present, as a SSA, Ethiopia has the fifth largest area devoted to maize but is second, only to South Africa, in yield and third, after South Africa and Nigeria, in production (CSA, 2013).

2.2. Maize Post Harvest Losses

PHL refers to the grain loss after harvesting until it reached to consumption (Nyambo, 1993). It is also considered as a grain loss in different forms such as quantitative weight loss, change of physical form and economic viability loss in the overall supply chain process after harvesting (Tefera, 2012; Aulakh & Regmi, 2013). A quantitative loss is to mean that loss of physical weight, which can be quartified in numerical values whereas qualitative loss is contamination of grain by molds and includes loss in nutritional quality, edibility, consumer acceptability of the products and the caloric value (Kader, 2005; World Bank, 2011). Economic loss is the grains financial value decrement due to a decline in quality and/or amount of food (Tefera, 2012). The worldwide accepted standardized measure of grain loss is weight loss (Lima, 1979) i.e. dry matter basis decline (Tefera, 2012).

A widely recognized constraint along grain value chains across the continent is PHL, and minimizing such losses could play an important role in reducing production volumes needed to feed a growing population (Rosegrant & Magalhaes, 2015). Likewise, every year across SSA, unacceptable levels of post-harvest food loss continue to occur. To illustrate specifically, PHL value in Eastern and Southern Africa alone reached about USD 1.6 billion year^{1} (World Bank, 2011), particularly cereals account over 40% of the total PHL in SSA countries (Rosegrant & Magalhaes, 2015). The aforementioned PHL is comparable with the normal calorie demand of 20 million people year^{1} (Murdock et al., 2003), or greater than half of the entire food aid worth received by SSA in a decade (Rosegrant & Magalhaes, 2015). Furthermore, maize PHL in developing countries under different storage structures stretched from 15-25% (Meronuck, 1987). Indeed, most farmers outlined weather fluctuations (40%), field pest damage (33%) and storage pests (16%) as the three major determinants that worsen PHL in SSA (Abass, 2014).

2.3. Maize Storage Techniques and Incidence of Pests

On any aspect, the general importance of storage techniques in various forms, i.e. either traditional or modern such as open field storage, polythene, jute bags, platforms tree storage etc. are to keep grains produced beside pest and theft, seeds preservation, quality enhancement, quantity equalization and optimum price stabilization for some anticipated time period (Sekumade & Oluwatayo, 2009).

According to Agboola (2001), storage techniques can be categorized into traditional and modern in SSA. Traditional techniques include calabashes, gourd, earthware pots, underground storage, jute bags, baskets and sacks, aerial storage (tree trunks), storage on the ground or on drying floors, open platforms; while modern techniques consist of reinforced concrete silos, steel bins, rhombus, improved traditional bins, solid wall bins, cribs, and silos. Those authors argued that effective farm storage allows the farmer to sell maize when the market price is optimum but with the existing traditional storage techniques, the market is subject to considerable price fluctuations. In this regard, different kinds of literatures organized for the types of storage techniques and what types of storage pests commonly occurred.

2.3.1. Traditional storage techniques

The traditional storage method in SSA for on-farm storage typically includes mud and thatch stores or simple gunny sacks, which were not air tightened that required to eliminate insect pests in storage (Kimenju & Groote, 2010). Despite the lack of knowledge of how to construct traditional mud granaries, take up of wider space, inability to move rapidly during an emergency such as fire or flood, and having lower consumer preference and price in the market, etc., are some of the demerits (World Bank, 2011). On this regard, it's obvious that grains stored in traditional techniques for six months had been damaged by insect pests such as LGB (Prostephanus truncatus), grain weevil (Sitophilus granarius) and lesser grain borer (Rhizopertha dominica) (ASSP, 2004).

The LGB (Prostephanus truncatus), particularly at the adult stage, is a sympathetic pest of stored maize that will attack the cob both before and after harvest. In East Africa, the estimated quantitative stored maize weight loss was as high as 35% after 3 - 6 months' storage. However, on average 19% weight loss after 6 months' storage has been revealed, and in some cases, it may extend more than 30% (GTZ, 2014).

The maize Weevil, Sitophilus zeamais Motschulsky, is a small reddish-brown to black snout beetle (Suleiman & Abdulkarim, 2014). It is described as one of the most destructive stored and primary grain pests of maize and grain in tropical and subtropical regions (Suleiman et al., 2015), which is so devastating and capable of multiplying to large populations, causing tremendous damage to the stored grain (Cosmas et al., 2012). On this aspect, Ojo & Omoloye

(2012) have estimated that 5-30% of the total grain weight of the stored product is lost due to infestation by maize Weevil. Likewise, as high as 80% loss may occur in untreated maize grain stored in a traditional structure (Tefera et al., 2011). Obviously, infestation by *S. zeamais* often begins in the field, but serious damage is done in storage (Abebe et al., 2009; Suleiman et al., 2015).

In spite of the noticeable damages caused by insects, birds, mice, and rodents, the role of storage fungi in the loss of stored grain cannot be ignored (Dunkel, 1988). Some storage insects are disseminators of storage fungi while others are the exterminations (Sinha, 1971). Fungi are well-known to cause a variety of deteriorating changes in grains and fresh produce, both before and after harvest (Sauer, 1988). It has been reported that fungi grow faster under warm conditions than under cool conditions. As a rule of thumb, deterioration is increased about 10 times faster at 25 ºC than at 3 ºC (Sauer, 1988; Rashid et al., 2013). According to Bankole & Mabekoje (2004), contamination of maize to fungi can be categorized into two main classes: the field and storage fungi. The field fungi are those that invade the developing or mature seed of cereal plant at moisture contents of about 20% (Christensen, 1957; Meronuck, 1987). Field fungi do not compete well under normal and dry storage conditions but may grow extensively in improperly preserved maize at high moisture (Meronuck, 1987). On the other hand, the storage fungi are those that develop on and within seeds at moisture contents often encountered in storage, the principal species are Aspergillus and Penicillium (Christensen, 1957). The major effects of storage fungi on grain are discoloration, germination loss, nutritional changes, heating, mustiness and musty odors. Also causes dry matter loss, Mycotoxins production, nutrition and chemical changes and reduction in processing quality (Meronuck, 1987; Sauer, 1988). The storage fungi do not invade grains before harvest (Christensen & Kaufmann, 1965). However, it is unknown what factors determine why field fungi primarily develop on the standing crop while storage species became dominant in store. Nevertheless, fungi are known well for their role to produce secondary metabolites or Mycotoxins. The most important and frequently encountered Mycotoxins in maize include the aflatoxin, fumonisin, ochratoxins, trichothecenes, deoxynivalenol, and zearalenone (Magan & Lacey, 1984).

2.3.2. Modern (hermetic) storage techniques

HS is a modern storage method to control insect infestation and preserve the quality of grain (Quezada et al., 2006). HS also termed as ‡hermetic silo storageˆ, ‡sealed storageˆ, ‡airtight storageˆ, as an alternative and cost-efficient methods for minimizing PHL and increases food security in developing countries (Villers et al., 2008; Essien et al., 2010). The basic principle of HS is based on the simultaneous depletion of oxygen and accumulation of carbon dioxide in the storage container (Sanon et al., 2011). This is achieved by the aerobic respiration of grain, insects, and molds (Quezada et al., 2006). The lack of O_2 inside the container causes insects to suffocate, become inactive and eventually die of asphyxiation or desiccation (Njoroge et al., 2014). The main advantages of HS are simple, feasible, eliminate the need of toxic chemical (insecticides) or fumigations, climate control and environmentally friendly (Navarro et al., 1994; Villers et al., 2008). HS is a technology that enables farmers to store their grains with negligible loss of quality and quantity.

Hermetic storage is categorized according to the amount of grain been stored, small quartity usually employs the use of bags and small containers, while huge or bulk storage employs larger storage facilities (Yakubu, 2012). For small quartity at household level, two types of HS container (bags) have been developed: Grain Pro Super Bags (Villers et al., 2008), and PICS and other HS includes metal silo technology and silo or grain bags for large amount of grain quantity at commercial level (Murdock & Baributsa, 2014).

PICS bag also known as the triple-layer bags consisting of three plastic liners. Two 80-micron high-density polyethylene plastic bags, one surrounded by the second; both are enclosed by a third bag made of woven polypropylene bag for reinforcement (Purdue University, 2014; Murdock & Baributsa, 2014). This technology was created in the late 1980€s under the United States Agency for International Development (USAID) project for the preservation of cowpea grain in SSA. The technology was named ‡Purdue Improved Cowpea Storageˆ bags and served as protection against Callosobruchus maculatus (F.) a destructive cowpea seed (bruchids) beetles (Murdock et al., 2003). According to Sanon et al. (2011) PICS is based on the principle of the bio-generated modified atmosphere, where oxygen environment low inhibits the growth and development of insect pests. It takes advantage of an airtight seal where oxygen concentration dramatically decreases while carbon dioxide levels proportionally increase within a few days after sealing through respiration of insect, fungal, and grains or seed (Quezada et al., 2006). A recent study of maize storage in small-scale metal silos found a near complete elimination of losses from insects, saving an average of 150-200 kilograms of grain, an increase of 1.8-2.4 months of storage duration, and a complete reduction in insecticide costs (Zachary et al., 2015)

2.4. Controlling Measures of Post-Harvest Losses

There are several methods for managing insect infestations in grain storage systems, including insecticides and fumigants, inert dust, biological agents, and various HS technologies (Obeng-Ofori, 2011). Likewise, Giles et al. (1995) added that intervention methods designed to reduce losses at smallholder level have relied mainly on the use of insecticides supplemented by cultural control methods such as the use of ash, botanicals and store hygiene.

Some of the modern technologies for controlling PHL include contact insecticides and fumigants, botanicals, inert dust, biological control agents, HS technologies in form of metal silos and high-density polyethylene that reduces gas exchange (Obeng-Ofori, 2011; Tefera et al., 2011). Similarly, Kimenju & Groote (2010) reported that insecticide treatment methods have become increasingly more common to protect against insects, particularly Actellic super „ a combination of 1.6% Pirimiphos-methyl and 0.3% Permethrin which is ubiquitous in Kenya and Tanzania. This method requires insecticide applied to dry maize, then reapplied approximately every three months depending on the local prominence of the maize Weevil and LGB, the main scourges of stored maize in East Africa. Additionally, Hugo et al. (2013) demonstrated that metal silos were effective in controlling maize Weevils and the LGB without the use of pesticides such as Actellic Super and Phostoxin. It was not known during the current study whether the farmers were able to handle or apply the chemical pesticides correctly according to the manufacturers' prescriptions, but Rugumamu (2011) previously highlighted the difficulties faced by farmers in Tanzania regarding the high cost, limited availability, and uncertain genuineness of the available pesticides. Nonetheless, there is sufficient evidence to suggest the need for increasing the skills and capacity of smallholder farmers, traders, transporters, marketers, and other stakeholders in the application of modern pest control measures. Because the majority of the farmers (96%) reported that they had limited knowledge in relation to the proper post-harvest management methods, especially for crop storage and pest control and 55% of them expressed the desire to receive training from agriculture extension officers on the management of pest and diseases.

According to the survey result conducted in the Kwara State of Nigeria, preventive measures such as chemical treatments were common for protecting the grains from storage pest attack. Even, some of the respondents use chemicals to fumigate their maize, and the sources of chemicals were cooperatives (42%), extension agents (31%), and other sources such as market (13%). Finally, most of the respondents (66%) confirmed the effectiveness of chemical application to stored maize by reducing pest damages (Sekumade & Oluwatayo, 2009)

2.5. Economics of Maize Storage Techniques

The concept of economics of maize storage techniques is a very broad concept since it includes demand, supply, distribution, production, etc. However, the scope of the study is more focused but not limited to the analysis of the demand side of storage techniques from a cross-sectional data at a given point in time. Therefore, for the purpose of this study, the economic costs and returns, and factors affecting farmers use of maize storage techniques were given consideration.

2.5.1. Economic costs and returns of maize storage techniques

The ability to store and length of storage time depends on the ability to wait till the stored maize command high price despite all constraints, the amount of input costs the farmer is willing to pay (WTP) for any storage technique (Pinckney, 1993). On this aspect, it is desirable to store when the post-storage value (revenue) surpasses the gross expenditures acquired in the storage process (Tierney & Waller, 1999). To know it, the information has to be obtained on the fixed and variable costs of storage. The volume of produce (maize) stored and the revenue (price multiplied by quantity) after storage. The analysis is refined by considering the utility of the product after storage. In this case, both fixed and variable cost of storage when estimating the storage viability, but only considered variable costs for profitability estimation (Andrew, 1999). To persuade the farmers of the economic benefits in storage, an increase in investment on modern storage must be shown to increase their revenue and GM. Gross profit (GP) or GM is a reliable guide to the operational performance of farm business (Warren, 1992). Likewise, Beti et al. (1995) stated that GM indicates whether it is worthwhile doing a business in any one period. Therefore, GM analysis results would have been reviewed and used as a base for the economic costs and returns implications of storage techniques. But, a priori, it is better to review the economics of existing and most practiced maize storage techniques by farmers.

According to Jones et al. (2011), the economic analyses of selected crops stored in PICS revealed that many of them were profitably stored. In line with this statement, Adefemi (2016) proofs the most profitable storage system was the crib with a profit of 83,813 N ton^{-1} of maize stored. This is followed by metal drums (81,667 N ton^{-1}), jute bags (42,064 N ton^{-1}), open platform (39,300 N ton^{-1}) and elevated barn (37,200 N ton^{-1}). Likewise Purdue University (2014) and Murdock & Baributsa (2014) added that HS can have many benefits besides financial ones which is available where the people who need it, simple, durable, culturally acceptable, scalable, sustainable, reduce or make unnecessary the use of insecticides on the stored crops, protecting both applicators and those exposed to the chemical directly or indirectly, as through food residues, etc. In addition, Hoffmann & Gatobu (2014) reasoned out that households may have their food safety and health jeopardized if they apply storage chemicals inappropriately or consumes grain that has been infected with mold and aflatoxin. However, the effectiveness of the hermetic technology depends on several factors such as airtightness of the seal, the commodity stored, agro-climatic conditions, type and prevalence of insect pests and mechanical strength of the barrier material (Njoroge et al., 2014).

According to the cost and return survey analysis result of Adetunji (2007), modern storage techniques usage is more profitable, with GM of 12,435 N ton^{-1}. Apart from the on-farm cost, which took the largest percentage of the cost share, transportation and labour cost also should be noted in maize storage business, it accounted for about 16% of the total variable cost (TVC) for farmers that sold green maize, whereby those stored (in any category) used 6-9% for transportation and labour cost. The results from the partial budget (PB) and marginal analysis (MA) shows that modern storage technology is the best among all the storage technologies which have the highest difference in GM (N 8,135) and highest MRR (1.10). Likewise, the survey result conducted by Sekumade & Oluwatayo (2009) in Kwara State of Nigeria profound that, the return on investment (RoI) for the four storage categories are; 0.12 (no storage), 0.20 (local storage), 0.26 (semi-modern), and 0.28 (modern technology). This implies that for every N 1.00 spent, 12kg, 20kg, 26kg and 28kg is gained using no storage, local, semi-modern and modern storages respectively. Moreover, they revealed the PB for maize farmers in their study. The difference in GM when farmer changed from ‘no’ storage to local, semi-modern or modern are N 4,045, N 6,835, N 8,135 respectively. These positive differences indicate the amount by which the GM of local, semi-modern or modern exceeds the GM of ‘no storage’.

Generally, by considering the aforementioned research results among storage techniques, it could be inferred that many of the respondents are using traditional storage techniques but tries to graduating from the use of traditional storage techniques to modern ones (Udoh et al., 2000; Agboola, 2001; SADC, 2008). It is due to the reason that the respondents can change to any of the storage technology which is best and preferred of the storage having the highest difference in GM (Adefemi, 2016). Therefore, for the purpose of this study, GM analysis would be used so as to analyze the economic costs and returns of maize storage techniques.

2.5.2. Factors affecting farmers’ use of maize storage techniques

According to a survey result conducted in Nigeria, 26.9% do not store at all, 20.2% makes use of Jute bags, 2.5% makes use of elevated barn, 43.7% makes use of cribs, 2.5% makes use of metal drums, 0.8% makes use of silo, and 3.4% makes use of an open platform (Adefemi, 2016). In another survey result, most (74%) of respondents used traditional/local storage structures, while the remaining 23% and 3% used semi-modern and modern storages, respectively. Though half of the respondents stored for more than 6 months, the storage loss accounts 8% (local storage) and 4% (semi-modern storage), nevertheless, negligible spoilage observed in modern storage (Sekumade & Oluwatayo, 2009). Therefore, anyone can simply imagine how subsistence farmers used traditional storages with lower per capita storage capacity, i.e. not more than 1.5 tones. The survey conducted in other places also have reported almost similar results (Gwinners et al., 1990; Daramola & Odeyemi, 2000).

Generally, farmers€ use of different maize storage techniques would be influenced by different factors either positively or negatively. Farmers decision to use local storage was negatively affected by capital invested and age. The coefficients were interpreted as a unit increment of capital invested and age, farmers€ decision to use no storage will increase by 0.0006% (p = 0.10) and 18.3% (p = 0.01) respectively. Likewise, the decision to use semi-modern storage was negatively affected by labour and transportation cost, but positively by the stored maize quantity; mean that a unit increase in labour and transportation cost drive the chances of using no storage by 0.2% and 0.53% (p = 0.10) respectively, but a unit increment of maize stored quantity will advance the uses of semi-modern storage by 16.7% (p = 0.01). Additionally, more explanatory variables were significantly affecting farmers€ decision to use modern storage techniques. Among them, the positively influenced factors were years of experience (2.6%; p = 0.01), educational level (5.6%; p = 0.10) and quantity of maize stored (16.3%; p = 0.10) whereas transportation cost (0.89%; p = 0.10) and age (75.1%; p = 0.01) negatively affected (Sekumade & Oluwatayo, 2009)

According to the survey result conducted in Nigeria, different factors were influencing farmers€ in using different maize storage techniques. Based on the result, capital invested and age are positively significant in the use of local storage at less than 10% probability level. In the case of semi-modern storage usage, household size (p = 0.05), labour cost (p = 0.1) and transportation cost (p = 0.1) are negatively significant while the quantity of maize stored is positively significant (p = 0.01). For the use of modern storage; age, years of experience, educational level of respondents, and the quantity of maize stored were positively significant, while household size and transportation cost were negatively significant. In addition, the marginal effects (ME) of each explanatory variable were displayed in the survey result. A year increase in age of the farmer will cause 0.1% decreases in the use of no storage by farmers; also a tone increase in the quantity of maize stored will bring about 0.12% decreases in the use. A 1 N increase in transportation cost will cause 0.0045% increases in the use of no storage. Also, an additional member of the farmer€s household will increase the use of no storage by

0.26%. For local storage, an additional year to farmers’ age also increase the use of local storage by 0.15% and an N increase in capital invested will cause an increase in the use of local storage by 0.00007%. For the use of semi-modern storage, an additional ton of maize stored will cause 0.08% increases in the use of semi-modern storage by the farmer, an additional member to the farmer’s household will cause a decrease in the use of semi-modern storage by 0.10%. An additional year to farmers’ experience and an additional year of education will bring about 0.049% and 0.82% increases in the use of modern storage technology, respectively. Also, a ton increase in the quantity of maize stored will cause 0.11% increases in the use of the storage. But an additional member to the farmer’s household will cause a decrease in the use of modern storage by 0.50% (Adetunji, 2007).

In general, based on the reviewed literatures, farmers’ decision to use maize storage techniques were influenced by socio-economic characteristics, investment costs, institutional setups, communication conditions, etc. however, the influential roles of communication conditions and users attributed values and perceptions on the storage techniques were not clearly investigated. Moreover, directions of influencing farmers’ decision to use any storage technique varied across the study areas. Therefore, for the purpose of the study, an effort would have paid to inculcate the whole explanatory variables including but not limited with socio-economic characteristics of farmers, institutional and communication conditions, and farmers attributed perceptions and values on the existing storage techniques.

2.6. Theoretical Framework

On the study of economic costs and returns of maize storage techniques, farmers are expected to prefer and use the available storage techniques which have the highest benefits and lowest cost implications. For the purpose of this study, farmers are considered as a consumer of the storage techniques, and there is a need to explain their preferences as a consumer. To explain consumer preferences on using maize storage techniques, it is better to refer Random Utility Theory (Lancaster, 1966). Based on this, HHs are expected to desire the alternative which has the highest perceived utility. Hence, a HH n would select storage technique i from a set of J maize storage alternatives only if this alternative has the highest perceived utility . The probability P that a HHs would choose the storage alternative from a choice set is:

= ( ) > "` -------------------------------------- (1)

Utility is further split into two portions, systematic portion and stochastic portion :

= + -- (2)

While the latter portion summarizes unobserved variation, represents the systematic and measurable portion of the utility function, which is generated by variables that can be observed by the researcher (Louviere et al., 2000)

2.7. Conceptual Framework of the Study

In general, studying the economics of hermetic storage is a broad and complicated issue since it includes the demand, supply, distribution, production etc. aspects. Therefore, selecting and investigating the most important aspects with the consideration of the study area would have a pivotal role in addressing the research objectives. For the purpose of this study, the economic costs and returns analysis of storage techniques, and determinants of farmers€ decision to use the existing storage techniques were given priority.

The theoretical background about HHs behaviour to use maize storage techniques would be based on the random utility theory. Smallholder farmers were expected to use a maize storage technique which have the highest economic benefits and the lowest cost implications from the existing alternatives to maximize their utility, under the normal conditions. However, despite the benefit and cost implications, various factors would affect their decision to use the relatively better storage techniques. Though multifaced factors were affecting their decision, the most relevant determinants, which was screened by the preliminary survey, for this study were socio economic characteristics, institutional and communication conditions, and perception and value on PICS.

Smallholder farmers€ Socio-economic characteristics are important institutional units that for most agricultural extension services delivery including but not limited to modern storage techniques usage. Thus, discussing the demographic and economic features of respondents and the inferential results would have a vital role to see the extents of PICS utilizations among rural households. Similarly, different research results attempted to display the influencing power of the aforementioned characteristics of the respondents in participation and utilization of full agricultural extension services (Elias & Karippai, 2014; Tenna, 2015, 2016b).

Institutional and communication conditions usually influence the HHs level of awareness about the existing storage techniques. Access and utilization of diversified media for information diffusion of storage techniques was very important to increase smallholder farmers€ awareness about the existing storage techniques. Therefore, it€s hypothesized that smallholder farmers€ who accessed and utilized information from diversified media about storage techniques would be at a better status of utilization. However, a HHs who used other agricultural inputs from cooperatives or other institutions is expected to have a lower utilization status of modern storage techniques.

Decision making at HHs level to use any storage technique depends on the value and perception towards the general attributes of the storage techniques. Based on the result of preliminary survey, the storage capacity and the material cost of the techniques were the highly prioritized variables though other variables were identified. Mostly smallholder farmers preferred to use a maize storage technique which have a relatively larger storage capacity and lower material cost.

The comprehensive investigation of economics of maize storage techniques could be done at household level, community level, or both. In fact, the purpose of investigation matters which unit of analysis would use. For the purpose of this study, detail analysis of economic costs and returns, and determinants of HHs decision to use maize storage techniques by using quantitative data for some selected variables would be conducted at household level. Moreover, qualitative analysis at community level for opportunities and challenges of maize storage techniques would be done so as to make the study comprehensive.

Therefore, by considering the aforementioned scenarios, the following conceptual framework is constructed so as to analyze the economic costs and returns of maize storage techniques plus the determinants of farmers€ decision to use them in the study area as an objective of the study.

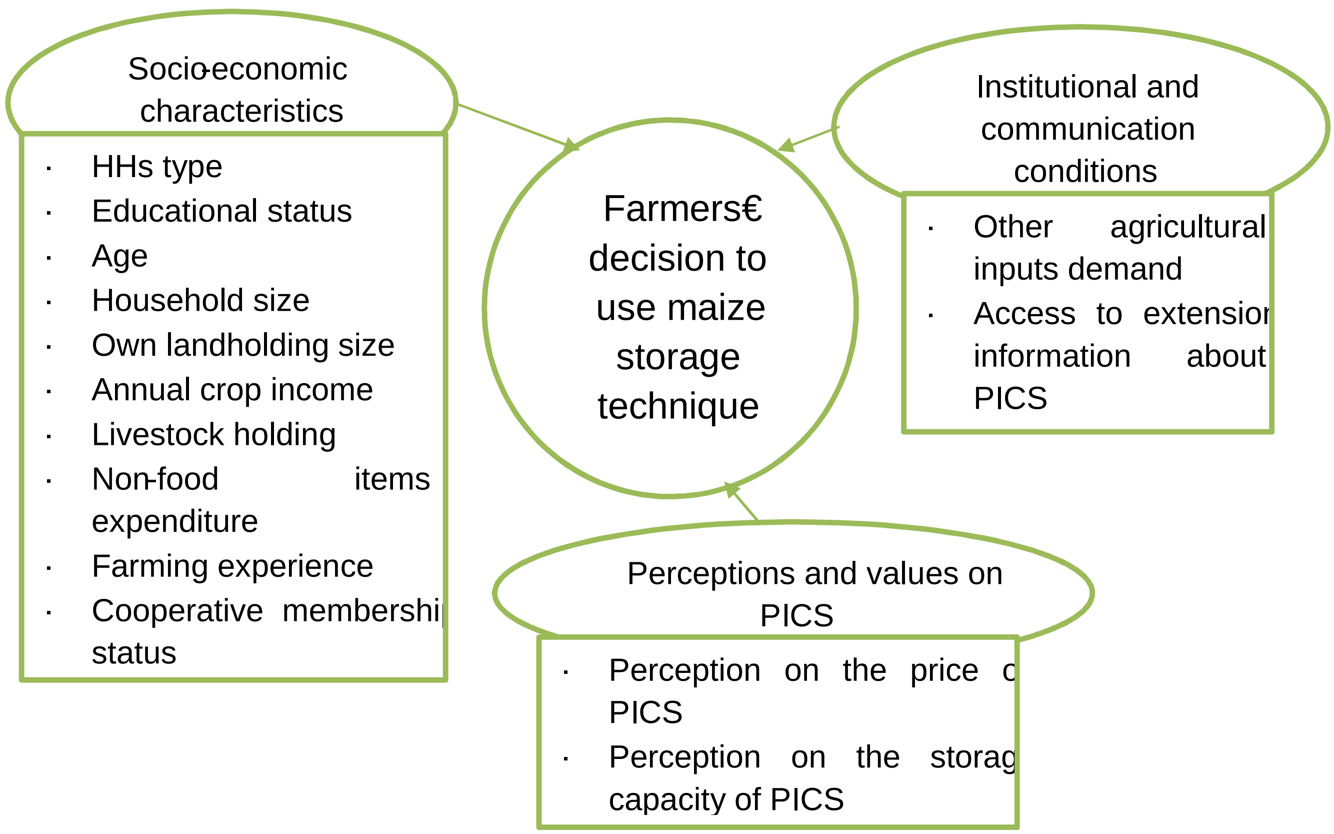

Figure 1. Own sketched conceptual framework of the study

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

West Gojjam is a Zone in the ANRS of Ethiopia. West Gojjam is named after the former province of Gojjam. West Gojjam is bordered on the south by the Abay River which separates it from the Oromia Region and Benishangul-Gumuz Region, on the west by Agew-Awi, on the North-west by North Gondar, on the North by Lake Tana, and the Abay River which separates it from the South Gondar, and on the east by East Gojjam. Its highest point is Mount Amedamit (WGZDA, 2016). The Zone has a total population of 2,106,596, of whom 1,058,272 are men and 1,048,324 women; with an area of 13,311.94 square kilometers, West Gojjam has a population density of 158.25. A total of 480,255 households were counted in this Zone, which results in an average of 4.39 persons to a household, and 466,491 housing units (CSA, 2007). The main source of an economy is land which used majorly for the crop (cereals, spices, pulses, vegetables and oil) and livestock production which is one of the integral components of the farming system. The Zone has been known for its high potential of maize, wheat, teff, and pepper production for supplying the produce for domestic market consumption (WGZDA, 2016).

3.1.1. Bure Woreda

Bure, located on the North-western part of Ethiopia is one of the 11th Woredas of West Gojjam Administrative Zone. Bure, the main town of the Woreda, located at a distance of 400 km from Addis Ababa and 148 km from Bahir Dar. The overall area of the Woreda covers 58, 795 ha and bordered by Jabitehnan and Dembecha Woredas in the East, Sekela Woreda and Awi Zone in the North, Womberma Woreda in the West and Oromia National Regional State in the South. The Woreda is divided into 19 PKAs and 1 Urban Kebele Administration (UKA), totally 20 kebeles. The total population of the Woreda is 116,076 of which 110,511 live in rural areas while 5,565 live in urban area. Among the 110,511 rural dwellers, 54,929 are male and 55,582 females. Among the rural population, the total numbers of household heads are 21,160 out of which 19,048 are male; 2,112 are female, and the average family size is 5.2 (BWoA, 2017).

Figure 2. Map of the study area (a) Regional States of Ethiopia, (b) Amhara National Regional State, and (c) Study areas (Womberma and Bure Woreda)

The topography of the area has different features; 76% gentle slope, 10% mountains and the remaining 14% is uneven land. The altitude of the Woreda ranges from 713 to 2604 m asl. The Woreda is classified into Dega (1%, comprises 3 PKAs), Weina Dega (77.23%, comprises 13 PKAs and 1 UKA) and Kola (21.77%, comprises 3 PKAs) agro-climatic zones. The Woreda receives an average annual rainfall ranges from 700 mm to 2350 mm. The long-term annual mean temperature of Bure ranges from 17 °C to 25 °C. In general, the dominant soil types of the Woreda are 20% brown, 17% black and 63% red in physical color. The soil of the Woreda is believed to be fertile and the Woreda is known by its high production per unit area. From the total 58,795 ha land of the Woreda, 30,677 ha (52.2%) is under cultivation with 29,629 ha (96.5%) annual crops and 1,048 ha (3.5%) perennial crops, whereas the remaining areas allotted for grazing land (3,081 ha), forest land (6,066 ha), bush land (8,280 ha), residence land (4,388 ha), land covered by water (186 ha) and 6,117 ha uncultivable land. The major crops grown in the Woreda are cereals, spices, pulses, vegetables and oil crops. The Woreda has been known for its high potential of pepper, maize, wheat and teff production for supplying the produce for domestic market consumption. Livestock is also reared by most of the households in Bure Woreda. Livestock production activity is one of the integral components of the farming system (BWoA, 2017)

3.1.2. Womberma Woreda

Womberma Woreda is bordered with Awi zone in North, Oromia Region in South West, Awi zone and Benishangul Gumuz Region in West, and Bure Woreda in Eastern direction. The total area comprised 13,5675 ha. The Woreda is divided by 21 PKAs. The total population of the Woreda reached up to 127,068 (Male: 66672; Female: 60396). The majority (68%) of the Woreda is comprised by Weina Dega agro-ecology, while the remaining (32%) is Kola. More than 75% of the coverage has a gentle slope, whereas the remaining 25% constitute mountainous hillsides. The highest altitude reached up to 2125 m asl, while the lowest is 783 m asl. The mean annual highest, medium and lowest rainfall were 1430 mm, 1250 mm, and 1100 mm respectively. Likewise, the mean annual temperature is ranging from 20 °C „ 33 °C. Among the total area of the Woreda, 32.2% (39020 ha) is under cultivation, 53.8% (65183 ha) is forest and bushland, 5.49% (6649 ha) is grazing land. The soil types dominantly composed of clay (65%) and clay loam (32%), which were suitable for cultivation of all types of crops. Almost all types of crops have been cultivating in the Woreda. Of which, maize, pepper, wheat, teff, barley, sesame, haricot bean, etc. are the mainly cultivated crops. Additionally, the place is suitable for livestock production. Cattle population takes the lion share (140,017) in livestock sectors, while the remaining constitutes about 13,408 (equines), sheep and goat (76,503), and poultry (94,895). In general, a mixed farming system had been practicing over the past couple of years (WWoA, 2017)

3.2. Sampling Design

Generally multistage random sampling was used to select the sample respondents. Firstly, two Woredas of West Gojjam Zone were purposely selected, i.e., Womberma and Bure. According to Purdue University (2014) the rationales behind the selection of the Woredas were relatively having the highest potentials in producing maize among all Woredas in the Zone, and PICS were distributed earlier in this area. Secondly, three PKAs from each Woreda, a total of six was selected purposely which had the highest potentials of maize productivity and relatively more number of PICS users. The selected PKAs were Zalma, Gulum Denjin, and Fetam Sentom in Bure Woreda, whereas Wogedad, Marquma, and Yergin from Womberma Woreda. Thirdly, by considering precision, homogeneity nature of samples and simplicity to analyze, simple random sampling technique by using RANDBTWEEN formula in Microsoft Excel sheet was employed to select 450 (Equation 4) sample HHs (66.7% user, and 33.3% non-user) from the total HHs that the selected PKAs have. The principle of probability proportional to size or ratio sampling was used as a basis to fix the number of sample HHs selected from each PKA and stratum.

In order to determine the sample size, the most frequent formula used for larger populations was employed (Equation 3).

$$= \frac{\quad}{\quad} = \frac{(\;.\;)\,(\;.\;)(\;.\;)}{(\;.\;)} = 385 \text{ HHs (Base Sample Size)} \text{------------------------} (3)$$

Where:

= Critical Value with 95%

= Population Variability or Estimated Proportion of Success with 0.5 (Maximum Variability for Larger Population)

= Estimated Proportion of Failure (1-)

= Range of errors with less than 5% (±5% Precision)

Assumed that the estimated response rate is 90%, the final sample size would be:

$$= 428 \text{ --- } (4)$$

For the purpose of management from the two stratum and other issues, a survey data is collected from 450 HHs.

3.3. Types and Sources of Data and Methods of Data Collection

The surveyed data was collected from both primary and secondary sources. Primary data directly collected from the respondents through an informal and formal survey. The informal preliminary survey was hosted also in two phases. In Phase I, semi-structured interview (SSI) and key informant (KI) interviews were conducted to collect background data about maize storage techniques in the study area. In this regard, KI interviews hosted PICS suppliers, local dealers, extension agents such as Woreda experts and Development Agents (DAs) etc., while SSI hosted individual farmers by using a checklist with the guided discussion. Likewise, In Phase II, group discussion (GD) and focus group discussion (FGDs) were held. In this phase, KI interviews was hold. This informal survey helped us to get more preliminary information about the study area in relation to the research under consideration which, in turn, critical to identify the potential explanatory variables which affected farmers€ decision on using maize storage techniques and to develop the structured questionnaire for formal survey. Generally, for the purpose of this research, a total of ten FGDs was conducted in two Woredas, and thirty KI interviewed. Lastly, but not the least, a formal survey was hosted via pre-tested individual interview schedule. Secondary data also collected from secondary sources like published (journals, proceedings, books, etc.) and unpublished (reports, manuals, packages, etc.) documents.

Qualitative and quantitative data regarding HHs demographic and economic features, farmer's traditions on maize storage techniques, descriptions of costs incurred and benefits earned from each storage technique, etc. were collected. Qualitative data which used to substantiate quantitative data was collected through an informal survey. Similarly, quantitative data also collected through personal interview using interview schedule.

3.4. Methods of Data Analysis

After completion of the data collection, data processing techniques like editing, coding, classification, and tabulation was done to make the analysis process simple and efficient. Finally, the processed data was entered to SPSS_25 and STATA version-15 statistical computer programs for analysis purpose.

Descriptive statistical tools such as frequency, mean, standard deviation, and ratio were used to explain different socio-economic characteristics, institutional and communication situations, perceptions and values on maize storage techniques, average storage length, and households reporting losses, etc. of the sample households. In addition, inferential statistical tools such as t-test and chi-square test employed to see the statistical significances of mean differences among continuous and dummy or categorical variables of different maize storage technique users, respectively. The hypothesized maize storage techniques were no storage (NS), traditional storage with pesticide (TSP), and hermetic (PICS) storage. Qualitative data also interpreted and described by using narrative explanation, categorization, and argumentative forms to supplement the findings of the quantitative data analysis.

3.4.1. Profitability analysis

The main output of this study is to compare the profitability of maize storage techniques and to recommend the one which is economically superior among many other alternatives. In this regard, one of the tools for estimating economic benefits of techniques applied to recommend the best technology is partial budgeting (Lessley et al.,1999) Similarly, Rodger et al.(2005) estimated PB for maize production under different weed control techniques by using MRR in order to choose the best techniques. Moreover, Hassan (1999) compared seven different maize storage technologies by using break-even price at two different discount rates. He found that traditional storage techniques with lower capital cost and no operating costs succeeded lower break-even prices in spite of higher losses.

Partial budgeting is a tool used to compare the cost and benefits of different choices faced by a farm business (Eckersley, 2004). The goal is to compare options by estimating the difference in gains or costs expected from them. According to Lessley et al.(1999), the PB has four categorical parts: additional income, reduced costs, reduced income and additional costs. The following steps are used in creating a PB.

: + = + --------------------------(5)

: + = + --------------------------(6)

: + " (+)--------------------------(7)

Where:

TAI= Total Additional Income of the New Technique
TRC= Total Reduced Cost of the Existing Technique
TRI= Total Reduced Income of the Existing Technique
TAC= Total Additional Cost of the New Technique

MA determines the effect of a change in farming activities. It shows the economic effect of changing from one treatment or technique to another (Alimi & Manyong, 2000). It involves calculation of MRR between techniques. MRR is a ratio of the change in GM to change in total variable input costs between techniques (Eckersley, 2004). The formula is specified as:

= ———————————————-(8)

= " ( ) " ( ) / " " ---------------------(9)

The GM of storage technique is specified as:

= " (")--------------------------(10)

Where:

= Gross Margin (ETB Qt^{-1})

= Price of maize crop in ith storage technique for jth respondent

= Quantity of maize crop in ith storage technique for jth respondent

= Price of variable input in ith storage technique for jth respondent

= Quantity of variable input in ith storage technique for jth respondent

I= 1•••.m

J= 1•• •... n

M= Types of storage techniques

n= Total number of respondents

3.4.2. Econometrics model specification

Farmers€ decision to use different maize storage techniques usually has co-dependent and coinciding characteristics (Dorfman, 1996). This is to mean that smallholder farmers use a combination of different storage techniques (Please See Also Figure 3) to reduce storage loss at a time. Therefore, multivariate modelling background is required to take in to account the interdependent and possibly coinciding features of their decisions (Greene, 2003). As a result, a Multi-Variate Probit (MVP) model was employed to identify the factors affecting HHs decisions to use maize storage techniques. In this case, the choice of techniques related to each other that corresponds to a dummy choice (yes/no) equation, and the choices are modelled jointly while accounting for the correlation among error terms (Nigussie et al., 2017). Model estimates from such specifications are superior to those from univariate specifications when the error correlations are significantly different from zero; otherwise, the two modelling contexts lead to similar results (Marra et al., 2017). Following Cappellari & Jenkins (2003), the model could be constructed in a system of coinciding Probit models for maize storage techniques as follows;

" = + = 1 " > 0 0 ! -------------------- (11)

Where

" = unobserved preferences of the farmer€s on the maize storage techniques m (= 1, 2, 3)

= the set of parameters that reflect the effect of changes in the vector of explanatory variables on the farmer€s preference towards the maize storage techniques

= the vector of observed variables that are expected to explain each type of maize storage technique

= error terms following a multivariate normal distribution, each with a mean of zero and a variance-covariance matrix with values of 1 on the leading diagonal and non-zero correlations as off-diagonal elements.

3.4.2.1 Workable hypothesis and variables specification

Dependent variable

The dependent variable is the HHs decision to use maize storage technique. It is a dummy variable taking the value 1 if the HHs decide to use each maize storage technique and 0 otherwise.

Independent variables

For maize growers to use maize storage techniques including but not limited to PICS as a strategy to reduce storage loss, they have to conclude that the economic benefits exceed the short term and long term costs implications on their livelihood. Having this under consideration and for the purpose of this research, according to the result of a preliminary survey, HHs decision to use storage techniques were hypothesized to have influence by a combined effect of various factors including but not limited to socio-economic characteristics, institutional and communication conditions, and perceptions and values on PICS. Theories and the findings of past related studies on farmers€ decision to use maize storage techniques, coupled with the researchers€ knowledge of the study area were used to select, structure, and hypothesize independent variables for this study. For the purpose of this study, explanatory variables influencing decision to use PICS has given due attention since the research focused on the economics of HS technique.

Age of the HHs (AGE): It is a continuous variable measured in the number of years. Agricultural extension services should consider age as an important characteristic for targeting not only from the point of view of youth but of other age categories. It has an important role in the extension process. It is obvious that young farmers are eager to get agricultural extension services. On the contrary, aged farmers were experienced to analyze the production and extension problems so that they accept primarily maize storage techniques. Therefore, the age of both FHHs and MHHs farmers was assumed to either negatively or positively influence the use of maize storage techniques.

Female HHs (FHHs): It is a dummy variable and takes 1 if the HHs is female and 0 otherwise. The FHHs is usually more worried than MHHs about storage losses since they are reserved on home and usually manages the stored grain product. Moreover, females are responsible for food availability and preparation issues so that they would be given due attention to storage losses. Therefore, this study anticipates that FHHs would be better accept improved maize storage techniques than MHHs if they get appropriate information.

Number of active labour force in the household (ACTIVELAFOR): It is the total number of members in a household, and has something to do with the economic dependency rate. Labour availability is a variable, which affects farmer€s decision regarding the adoption of new agricultural practices or inputs (Adesina & Baidu-Forson, 1995) When household size conversion to adult man equivalent is high the HHs utilization in new agricultural practice could increases. Thus, it is hypothesized in this study that household size is positively correlated towards the HHs use of maize storage techniques, i.e. mostly improved techniques.

Literate HHs (EDUCAT): It is a dummy variable and takes 1 if the HHs is literate, and 0 otherwise. It represents the HHs status of education, i.e. whether they are illiterate or literate. The study assumes that literate HHs could easily understand the extent of maize storage loss so that they easily decide to use PICS in order to reduce storage losses. Therefore, the study anticipates relatively literate HHs have better motivation and decide to use PICS.

Farming experiences of the HHs (FAREXP): It is a continuous variable measured in the number of years that HHs acquired farming experiences. Any agricultural extension service including storage techniques should consider the farming experiences of the HHs since it has great role in the production and conservation process. It€s obvious that the more experienced farmers are eager to get extension services and adopt any technology easily. Thus, this variable hypothesized to have a positive influence on the decision to use PICS in the study area.

Cooperative membership status (COOPME): It is expressed in terms of the number of years since a HHs joined rural cooperatives. A HHs who joined rural cooperatives earlier would have more experience and easily accessed and utilized any extension and development information.

The assumption behind this variable was all HHs are members of rural cooperatives, which was also ascertained by the survey result. Thus, it is hypothesized that COOPME positively influenced a farmers use of maize storage techniques.

Own landholding size (OWNLAND): Basically, in the study area, HHs land holding size is cumulative of either privately owned or rented or both. For the purpose of this study, the privately owned land is given due attention. Therefore, it refers that the total size of farm land in hectare privately owned by a farmer without rented or other land acquiring mechanisms. The more the arable land means the higher the agricultural produce on average to a HHs as a result of proper agronomic practices. This is to mean that the more yield a HHs produce, a storage technique with the largest capacity needed. On this case, since the maximum storage capacity of PICS is 100 kg plus its higher price, HHs preference to use PICS would be low. Thus, it is hypothesized in this study that the privately owned farm size is negatively and significantly influence the decision of a HHs to use PICS.

Livestock holding size (LIVH): It is a continuous variable measured in tropical livestock unit (TLU). Different research results confirmed that farmers who owned more livestock have the capacity to bear risks of using available extension package. Thus, it is hypothesized in this study that livestock is positively and significantly correlated with the use of maize storage techniques by farmers.

Annual crop income (ANNCRI): A high standard of living in the rural farming community is a reflection of the achievements and ability to bear the risk. It is thus assumed that annual crop income is positively associated with agricultural extension services including reduction of PHL. Farmers with a high standard of annual crop income are hypothesized to be more likely to adopt improved maize storage technologies than farmers experienced the low level of living.

Annual maize yield (MAYLD): It refers to the amount of average annual maize yield obtained from a given acre of land at HHs level. The increment of annual maize yield urges the necessity of more PICS with large storage capacity. However, in the study area, the maximum amount of PICS storage capacity is 100 kg. This may probably make farmers not to prefer and use PICS, plus its€ higher price under consideration. As a result, this variable is anticipated to influence the HHs decision to use PICS negatively.

Non-food items expenditure (NONFOIE): This is the annual expenditures for school fee, health, transportation, etc. other than food items. The more expenditures for non-food items would reduce the bargaining power of HHs to buy and use PICS, i.e. creates income deficit. Thus, HHs decision to use PICS would be minimized when the non-food items expenditure rise.

Other agricultural inputs demand (OINPUT): It is a dummy variable and takes 1 if the HHs uses other agricultural inputs, and 0 otherwise. It refers to the status of HHs access to demand other agricultural inputs from different sources. Access to demand of other agricultural inputs reduced the tendency of HHs decision to use PICS.

Access to extension information about PICS (EXTENSION): It is a dummy variable and take 1 if the HHs has accessed and utilized information from different media, and 0 otherwise. Access and/or contact to radio, TV, printed materials, public meeting, extension workers, demonstrations, etc. were considered as the important tools to provide relevant information about PICS. Any effort to disseminate agricultural technologies is mainly successful if there is the effective dissemination of extension information. Thus, it is hypothesized that access to extension information about PICS influences farmers€ decision to use modern storage techniques positively.

Perception on the price of PICS (HIGPRIC): It is a dummy variable and takes 1 if the HHs perceive the price of PICS is high, and 0 otherwise. It€s obvious in demand theory that when the price of input increases, the demand will decrease. Therefore, farmers€ perception of the set price of PICS affects their decision to use PICS negatively.

Perception on the storage capacity of PICS (SUPHUPIC): It is a dummy variable and takes 1 if the HHs perceive PICS has higher storage capacity than others, and 0 otherwise. This is the perception related factor based on the storage capacity of PICS. Most often, farmers prefer to use a storage technique with larger capacity so as to minimize the initial and other operational costs. Therefore, it affects HHs decision to use PICS in a positive manner.

Summary of the independent variables used in the model

Table 1 shows a summary of the independent variables that have been included in the model, their description, measurement, and type

Table 1. Descriptions, measurement and types of variables

Variable	Description	Measurement	Variable Type
AGE	Age of the HHs	Years	Continuous
FHHs	Sex of the HHs	1= FHHs, 0= Otherwise	Dummy
ACTIVELAFOR	Active labour force	Number	Continuous
EDUCAT	Educational status of the HHs	1= Literate, 0= Otherwise	Dummy
FAREXP	Farming experiences of the HHs	Years	Continuous
COOPME	Cooperative membership status	Years	Continuous
OWNLAND	Own landholding size	Ha	Continuous
LIVH	Livestock holding size	TLU	Continuous
ANNCRI	Annual crop income	ETB	Continuous
MAYLD	Annual maize yield	Quintal	Continuous
NONFOIE	Non-food items expenditure	ETB	Continuous
OINPUT	Other agricultural inputs demand	1= Yes, 0= Otherwise	Dummy
EXTENSION	Access to extension information abc PICS	1= Yes, 0= Otherwise	Dummy
HIGPRIC	Perception on the price of PICS	1= High, 0= Otherwise	Dummy
SUPHUPIC	Perception on the PICS storage capacit	1= High, 0= Otherwise	Dummy

4. RESULTS AND DISCUSSION

This chapter primarily discusses the general economic costs and benefits of maize storage techniques in the study area to address the first objective. Secondly, the factors affecting HHs decision to use maize storage techniques presented in an appropriate manner by using both descriptive analysis and econometric model results to fulfill the second objective. Finally, opportunities and challenges of maize storage techniques, in particular, attention with PICS is discussed. The discussions parts in the first objective mainly focus on comparing the three types of storage techniques (NS, TSP, and PICS). Moreover, in the second objective, the descriptive analysis compares the two (PICS users and non-users) group, while the econometrics model result estimated the coefficients of determinants from the three types of storage techniques or scenarios to show the differences in different dimensions.

4.1. Economic Costs and Benefits of Maize Storage Techniques

Different literatures and research results recommend that before analysing the costs and returns implications of any storage techniques, assessing the existing storage techniques and statuses of utilization, causes and management strategies of damage, and their preferences from different dimensions would have been scanty (Hassan, 1999; Adejumo & Raji, 2007; Adetunji, 2007; Sekumade & Oluwatayo, 2009; Adetunji, 2009b). For the purpose of the study, the aforementioned issues were assessed in the study area. Based on the survey result (Figure 3), out of the total (450) respondents, 87.8% (395), 66.7% (300), and 19.6% (88) respondents were practicing TSP, PICS, and NS respectively. It's obvious that in SSA, most farmers have been using traditional storage structure, and usually, they didn't store their maize product. Survey results in Nigeria proofs that 38% of the farmer used local storage, 31% did not store, and only 11% used modern storage (Adetunji, 2009a; Sekumade & Oluwatayo, 2009). Similarly, a survey result conducted in Kenya depicted that more than 53% of the farmers store their maize in a room in the living house, 21.6% stored in traditional structures, and only 0.3% stored in modern storage technique (metal silo) (Kimenju & Groote, 2010; Hugo & Jonathan, 2013).

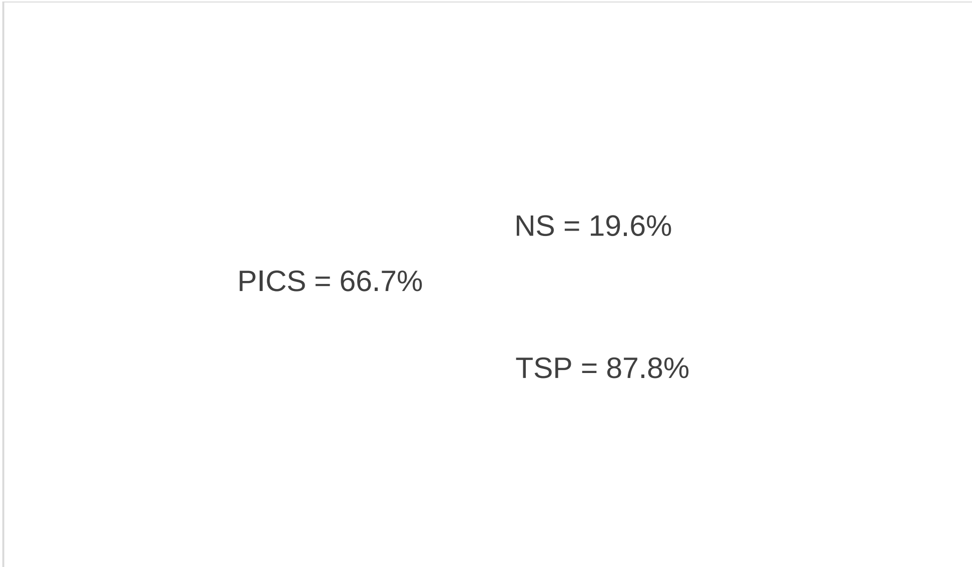

Figure 3. HHs status of maize storage techniques usage

On average, one HHs uses more than one storage techniques. Moreover, the proportion of HHs using pesticide was higher by 31.7% of PICS users. Thus, the severity of pesticide is on demand. This survey result is also in line with the information gathered during the FGDs and KI interviews. Most of the participants raised and discussed that pesticide usage for reducing the losses of storage pest is relatively higher. This is due to the high maize yield potential of the area. Moreover, they focused on the adaptation and resistance of pests to chemicals coerced us to use more chemicals. In general, according the information obtained from FGDs, financial crises and grain loss are the major issues in the study area.

According to the result of Table 2, more than half (54.9%) of the respondents reported that there is an occurrence of stored maize damage due to storage pests (93.5%) and rodents (65.6%). As a result, farmers were using different cope up strategies like pesticide (92.3%), cultural methods by using cat (52.6%), rodenticide (42.5%), PICS (19,8%), and selling immediately (13.8%). However, 203 (45.1%) respondents were suffering from the storage damage due to the early application of pesticide (81.8%) and the existence of PICS (72.4%). In general, the aforementioned result related to storage loss is common in SSA, i.e. many respondents (>80%) were complained about storage loss, especially with the use of local storage and/or with pesticide (Nyambo, 1993; Hassan, 1999; Murdock et al., 2003; Sekumade & Oluwatayo, 2009;

Adetunji, 2009a; Kimenju & Groote, 2010; Abass, 2014). In Ethiopia, it€s also estimated to be 5-26% as a result of using traditional storage structure (Befikadu, 2012; Hengsdijk & de Boer, 2017). The result depicted that the severity of stored maize damage is high at the household level as a result of different but interweaved causes. Likewise, different cope up strategies was implemented at household level including but not limited to chemical applications. Thus, one can simply imagine the extent of chemical applications and its negative consequence on health, environment, etc. On this aspect, understanding the role of modern storage techniques in averting the usage of chemicals for reducing storage damage would be vital.

Table 2. Trends on the occurrence of maize storage damage

Description	Category	N	Frequency	%
Occurrence of maize storage	No	450	203	45.1
Damage	Yes	450	247	54.9
Reasons for occurrence of	Pests	247	231	93.5
maize storage damage	Rodents	247	162	65.6
Cope up strategies of maize	Pesticide	247	228	92.3
storage damage	Rodenticide	247	105	42.5
	PICS	247	49	19.8
	Cultural Methods (Cat)	247	130	52.6
	Selling Immediately	247	34	13.8
Reasons for no occurrence	Use of PICS	203	147	72.4
maize storage damage	Early Application of Pesticide	203	166	81.8

Source: Own Computation (2018)
Where: N = Number of Respondents % = Percent

Different research findings showed that any financial costs and benefits analysis most often primly requires the qualitative judgment of beneficiaries behind their WTP and decision to use (Hassan, 1999; Adetunji, 2009b; Sekumade & Oluwatayo, 2009; Kimenju & Groote, 2010). Based on this premise, HHs perception of some qualitative parameters of different maize storage techniques was made and results presented in Table 3.

Out of the total respondents (450), the major (408) which accounts 90.7% of respondents prefer to use PICS primarily. Next, they like to use TSP as a second preference with 88% proportion. The least preference is vested on NS that accounts for 89.6%. This result indicated that despite their economic expenditure and other obstacles, they need to use PICS as a strategy to store maize.

Table 3. HHs perception on the general importance of maize storage techniques

Descriptions	Category	Types of maize storage technique (N=450)					
		NS		TSP		PICS	
		Frequency	%	Frequency	%	Frequency	%
Preferable rank	First	23	5.1	20	4.4	408	90.7
	Second	24	5.3	396	88.0	26	5.8
	Third	403	89.6	34	7.6	16	3.6
Level of market price during sale	Low	314	69.8	47	10.4	48	16.0
	Medium	58	12.9	301	66.9	28	9.33
	High	78	17.3	102	22.7	224	74.7
Level of initial investment cost	Low	450	100	-	-	-	
	Medium	-	-	450	100.0	1	0.33
	High	-	-	-	-	299	99.7
Necessity of pesticide	No	450	100	-	-	300	100
	Yes	-	-	450	100.0	-	-
Extent of storage pest damage	Nothing	450	100	59	13.1	300	100
	Low	-	-	156	34.7	-	-
	Medium	-	-	198	44.0	-	-
	High	-	-	37	8.2	-	-
Level of damages on human health	No	450	100			300	100
	Yes	-	-	450	100.0	-	-
Ecofriendly conditions	No	-	-	450	100.0	-	-
	Yes	450	100	-	-	300	100

Source: Own Computation (2018)

Where: N = Number of Respondents % = Percent NS = No Storage or Selling Immediately
TSP = Traditional Storage Technique with Pesticide PICS = Purdue Improved Crop Storage

(NB: N for PICS users were 300 except for the first parameter, i.e. preferable rank (N = 450) since it was assumed to be compared among the existing storage techniques).

Another parameter which should be considered for economic costs and benefits analysis is the respondents€ perceptions of the level of market prices during the selling time. Based on this assumption, an assessment was made to capture the respondents€ preferences on the market prices based on each storage techniques and the results were displayed in Table 3. Based on the result, the high rank is vested on PICS (74.7%), followed with a medium of TSP (66.9%) and a low of NS (69.8%). Though the TSP€s had a medium rank for the level of market price during the sale, it€s feasibility is too low since the use of excess pesticide is questionable and the differences in market prices with NS is negligible (Please Refer to Table 4). According to the information obtained from FGDs, almost all farmers in the study area preferred to use PICS technique. However, the high level of its initial cost (39.69 ETB) is a great barrier in addition to its wider area requirement and storage capacity.

Additionally, an assessment was done on the level of initial investment costs among storage techniques. As a result, the low rank of NS took the lead by 100%, in contrary with the highest rank of PICS that implied 99.7% too. The level of initial investment costs rank for TSP was medium, which is in between of the aforementioned two storage techniques. The above result, i.e. the highest preference rank level of initial investment costs of PICS, clearly showed how the investment costs could be a barrier for smallholder farmers€ decision to use storage techniques. Therefore, optimizing the initial investment costs by considering the bargaining power of farmers would be crucial.

The necessity of pesticide is also an important parameter which should be investigated so as to select the eco-friendly storage techniques. Based on this aspect, the survey result on Table 3 depicted that NS and PICS doesn€t need any pesticide so that there are no damages on human health and perceived as eco-friendly, while TSP needs pesticide, and perceived as it has negative impacts on human health and not-eco-friendly. Additionally, there is no perception record on the storage damage in NS and PICS. However, TSP significantly accompanied storage damage in a range of medium (44.0%), and low (34.7%). Overall, on FGDs, respondents perceived that PICS has a general importance, whereas NS and TSP don€t have it. Though PICS is primarily perceived to have health benefits and keep grain clean, its initial cost which is relatively high delays the quick adoption. In addition, despite the excessive use of pesticides, inputs costs, health and environmental impacts, etc., TSP incurred a high level of storage loss (Please Refer Table 4) on smallholder farmers in the study area.

4.1.1. Gross margins analysis

The survey result in Table 4 showed the profitability of each storage technique practiced by farmers in the study area with the given storage duration and selling price. Before, discussing on the profitability aspect, the specific variable costs incurred by maize grower farmers in the study area were identified and discussed. In general, the higher material price cost would probably decrease the GM that HHs earned from each storage technique. As a result, it would probably negatively affect the HHs decision to use it (Adetunji, 2009a).

Table 4. Estimated gross margins for each type of maize storage technique

Description	Types of maize storage technique (N=450)		
	NS (N=88)	TSP (N=395)	PICS (N=300)
Average duration of storage (Month)	-	5.4	9.6
Average selling price (ETB Qt^{1})	408.1	462.8	563
Average material cost (ETB Qt^{1})	9.42	9.35	39.69
Average chemical cost (ETB Qt^{1})	-	88	-
Average transportation cost (ETB Qt^{1})	18.36	9.35	8.24
Average loading and unloading cost (ETB Qt^{1})	7.52	7.29	6.31
Average cost of time wastage during selling (ETB Qt^{1})	8.52	8.65	9.81
Average cost of dry weight loss (ETB Qt^{1})	-	23.58	-
Average cost of storage pest damage (ETB Qt^{1})	-	52.06	-
Total variable cost (ETB Qt^{1})	43.82	198.28	64.05
Gross margin (ETB Qt^{1})	364.28	264.52	498.95

Source: Own Computation (2018)

Where: N = Number of Respondents; NS = No Storage or Selling Immediately; TSP = Traditional Storage Technique with Pesticide; PICS = Purdue Improved Crop Storage

Material cost

For the purpose of this study, the material cost refers to a cost incurred by farmers to buy and/or construct a storage either from the market or locally available materials. Usually, a commonly known bags which are called in local language "Madaberia", "Akumada", "Kiesha" is available in the local market for NS and TSP, while PICS is a standardized storage material made by PU. Both storage bags have a size of 100 kg. Of course, PICS has different packaging size. However, 100 kg storage size is commonly used by farmers in the study area. Additionally, the study used average material cost since there is a year variation on using PICS with different price levels. Based on this assumptions, PICS had the highest average material cost, i.e. 39.69 ETB Qt^{-1} followed by NS (9.42 ETB Qt^{-1}) and TSP (9.35 ETB Qt^{-1}). The insignificant variations of material costs between NS and TSP are due to time on such a way that the price differs accordingly. The distribution of the material cost share in the TVC was likely too high in PICS (62%) followed by NS (12.5%). Whereas, the least material cost share was relying on TSP (5%). This result clearly showed that TSP has the more variables cost list items than other storage techniques implying that the TVC is expected to be high.

Chemical cost

This is the average pesticide cost incurred to buy a chemical and used during when farmers store maize. The sole owner of this cost was the one who used TSP since the rest storage techniques don€t require pesticide. It€s the highest cost which accounts for 44.38% of the variable costs in TSP. On average, one HH incurred 88 ETB Qt^{-1} for pesticide, which has a purchasing power to buy at least two PICS. This result clearly showed the occurrence of the perception gap on the awareness of PICS. Different research results profound that the chemical cost usually accounts for 4-6% of the total cost in Nigeria and Kenya (Adetunji, 2009b; Sekumade & Oluwatayo, 2009)

Transportation cost

This is the average cost incurred for transporting maize from the home to the market place. Usually, equine driven carts were used for transportation purpose. Of course, a vehicle was used in some place which has the favourable infrastructure. Based on this aspect, the highest transportation cost was incurred for NS, i.e. 18.36 ETB Qt^{-1}. Almost TSP and PICS have similar average transportation costs, i.e. 9.35 ETB Qt^{-1} and 8.24 ETB Qt^{-1} respectively. The peak production season of maize and selling time makes the highest transportation cost in the case of NS. When the production season and selling time got off, i.e. storage duration increases, the transportation cost reduced gradually by 1.11 ETB Qt^{-1}. This price difference would be significant for a HHs who produce more maize, and for Woreda level. The great value of storage duration got the clear image under this investigation.

Loading and unloading cost

Usually, this cost is incurred for daily labourers to load and unload the maize to and from carts and vehicles. The highest and lowest cost was recorded in NS and PICS, i.e. 7.52 ETB Qt^{1} and 6.31 ETB Qt^{1}, respectively. The medium cost was from TSP (ETB Qt^{1}). This result is also a clear indicator of the time value of storage, i.e. decreasing of the costs with the increase of storage duration.

Cost of time wastage

This is the economic costs incurred by the HHs during the selling of the product. On this aspect, there is a high time wastage in PICS which accounts for 9.81 ETB Qt^{1}, while the NS have the lowest time wastage (8.52 ETB Qt^{1}). The TSP accounts a value of 8.65 ETB Qt^{1}. If we consider the selling price among storage techniques, the cost of time wastage differences would be unquestionable.

Cost of dry weight loss

This is the average economic cost as a result of the loss of moisture content after storage that was estimated by the individual HHs. The assumption behind is the cost of dry weight loss increases with a longer duration of time under normal conditions. Thus, the NSP incurred most expenses (23.58 ETB Qt^{1}) relative to others. This is the third largest variable cost (11.89%) that should be given consideration on selecting maize storage techniques. Neither NS nor PICS incurred any cost on this direction. Though the longest storage duration PICS has, there were no costs incurred due to the special air tight nature of the technique. Some of the research findings in Ethiopia confirmed that most of the dry weight loss extends to more than 10% of the stored value (Befikadu, 2012; Hengsdijk & de Boer, 2017)

Cost of storage pest damage

This is the average economic cost as a result of the insect pest damage. Though the level of insect pest damage varied across the respondents, the average cost of damage from the HHs judgement during sale was taken for estimation purpose. The NSP storage technique is the only one which has the second largest variable cost (52.06 ETB Qt^{1}) as a result of pest infestation. This almost accounts 62.26% of the TVC and can buy at least one PICS. Therefore, anyone can simply imagine the extent of loss due to the low level of farmers€ perception, pest infestation, etc. at HHs and Woreda level despite its effect on health and the environment.

Gross margins

The above result from Table 4 showed the TVC and GM derived by maize growers using different storage techniques. The highest and lowest TVC is derived from TSP and NS, i.e. 198.28 ETB Qt^{-1} and 43.82 ETB Qt^{-1} respectively, while PICS had relatively an optimum TVC (64.05 ETB Qt^{-1}). The highest TVC ratio of TSP to NS (4.5:1) and PICS (3.1:1) was a clear indicator to ignore this storage technique from choices in the basket. Moreover, further profitability analysis would not require under this situation since it€s dominated, i.e. having the lower GM (264.52 ETB Qt^{-1}) from the previous storage technique (NS) (364.28 ETB Qt^{-1}). The best GM was derived from PICS (498.95 ETB Qt^{-1}). Therefore, from the estimate, PICS is the most profitable, followed by NS. Selling maize is not as profitable as after storage with pesticides.

4.1.2. Partial budget analysis

Table 5 showed detailed results of PB for maize growers. Differences in GM when they change from NS to TSP and PICS are -99.76 ETB Qt^{-1} and 134.67 ETB Qt^{-1} respectively. Moreover, the difference change in GM from TSP to PICS was 234.43 ETB Qt^{-1}. The positive differences indicated the amount by which the GM of PICS exceed the GM of NS and TSP. On the contrary, the negative difference indicates the amount by which the GM of TSP lowered the GM of NS. If a HHs decided to use TSP rather than NS, he/she would be incurred -99.76 ETB Qt^{-1} additional cost. But, an additional 134.67 ETB Qt^{-1} profit would be gained if a HHs shifted to PICS. Additionally, if a HHs decided to shift from TSP to PICS, an extra profit of 234.43 ETB Qt^{-1} would be obtained. This implies that the maize growers can change to any storage techniques except TSP since it has a negative GM difference. From the whole, PICS is the best storage technique because of its highest GM difference, and TSP is the worst one since it has a negative GM difference. The aforementioned result is in line with most of the research results conducted in SSA that modern storage techniques have the highest GM (Adetunji, 2009b; Sekumade & Oluwatayo, 2009; Jones et al., 2011)

Table 5. Estimated partial budget analysis for each type of storage technique

Changing from NS to TSP				Changing from NS to PICS				Changing from TSP to PICS			
Positive Effect	Value/ETB	Negative Effect	Value/ETB	Positive Effect	Value/ETB	Negative Effect	Value/ETB	Positive Effect	Value/ETB	Negative Effect	Value/ETB
TAI	462.8	TRI	408.1	TAI	563	TRI	408.1	TAI	563	TRI	462.8
TRC	43.82	TAC	198.28	TRC	43.82	TAC	64.05	TRC	198.28	TAC	64.05
Total A	506.62	Total B	606.38	Total A	606.82	Total B	472.15	Total A	761.28	Total B	526.85
Total A minus Total B			-99.76				134.67				234.43

Table 6. An estimated marginal rate of returns analysis for each type of storage technique

Description	Types of Maize Storage Technique NS (N=88)	TSP (N=395)	PICS (N=300)
Average selling price (ETB Qt^{1})	408.1	462.8	563
Average total variable cost (ETB Qt^{1})	43.82	198.28	64.05
Gross margin (ETB Qt^{1})	364.28	264.52	498.95
Change in GM between two consecutive techniques (ETB Qt^{1})	-	-99.76	134.67
Change in total variable costs between two consecutive techniques (ETB Qt^{1})	-	154.46	20.23
MRR	-	-0.6459	6.657

Source: Own Computation (2018)

Where: N = Number of Respondents NS = No Storage or Selling Immediately

TSP = Traditional Storage Technique with Pesticide PICS= Purdue Improved Crop Storage

TAI = Total Additional Income TRC = Total Reduced Cost TRI = Total Reduced Income TAC = Total Additional Income

In the marginal analysis, only GM and TVC are used for the estimation of MRR ratios. The MRR of changing from one technique to another in this study is also displayed in Table 6 Based on the result, changing from NS to TSP is not recommended because its MRR is not only the lowest but also have a negative value (-0.6459). The MRR ratio when the storage technique shifted from NS to PICS was 6.657. This implies that if a HHs is shifted the storage technique from NS to PICS, the profit will increase by 665.7%. The result clearly showed the feasibility of promotion of changing maize growers storage technique from NS to PICS because of its highest MRR (6.657). Different results conducted in SSA confirmed that using modern storage technique other than traditional storage structures would have the highest GM, GP, MRR (Adetunji, 2007, 2009b; Sekumade & Oluwatayo, 2009; Jones et al., 2011; Adefemi, 2016.)

4.2. Factors Affecting Households Decision to Use Maize Storage Techniques

4.2.1. Descriptive analysis

According to the survey result (Table 7), almost all respondents were aware of PICS on 2015 (59.4%), 2014 (30.2%) and 2013 (9.2%) from extension workers (99.3%). Only 26 (5.8%) respondents were not aware of PICS.

Table 7. Households general awareness about PICS

Descriptions	Category	HHs (N=450)	
		Frequency	%
Awareness status of PICS	Not aware	26	5.8
	Aware	424	94.2
Years of awareness	2015	252	59.4
	2014	128	30.2
	2013	39	9.2
	2012	5	1.18
Sources of awareness	MPCSs	2	0.47
	SG 2000	1	0.24
	Extension workers	421	99.3

Source: Own Computation (2018)
Where: HHs = Household Heads N = Number of Respondents % = Percent

Though maize farmers aware of PICS, implementing a survey two year after the technology was introduced in the study was very short - the utilization is expected to be low. Moreover, the dissemination of PICS technology was limited, i.e. significantly concentrated in some areas (PKAs or villages) but not others given the limited resources.

Out of the surveyed respondents, more than half (66.7%) of them used PICS as maize storage technique which started from 2015 (59.3%), 2014 (33%) and 2013 (7.7%) (Table 8). On average, one HH has used only 2 PICS with 2 Qt storage capacity with the minimum of one and a maximum of fifteen (Table 9). The remaining, i.e. 33.7% of respondents, don't use PICS due to the probable reason of higher price (74.7%) and not easily accessible (43.3%) (Table 8). Accordingly, 8.7% of respondents reported the occurrence of problems associated with using of PICS including but not limited with attacked by rodents (76.9%), needs large space (42.3%) and internal plastic easily damage (7.7%). The good thing is 91.3% of respondents didn't suffer any problems as long as they used PICS for the last two years.

Table 8. Households status of PICS utilization

Description	Category	N	Frequency	%
PICS utilization status	Non users	450	150	33.3
	Users	450	300	66.7
Years of utilization	2015	300	178	59.3
	2014	300	99	33.0
	2013	300	23	7.7
Occurrence of problem when using PICS	No problem	300	274	91.3
	Problem	300	26	8.7
Types of problems	Attacked by rodents	26	20	76.9
	Needs large space	26	11	42.3
	Internal plastic easily damaged	26	2	7.7
Reasons for not using PICS	Higher price	150	112	74.7
	Not easily accessible	150	65	43.3

Source: Own Computation (2018)
Where: HHs = Household Heads N = Number of Respondents % = Percent

Table 9. Summary statistics of PICS utilization status

Descriptions	N	Minimum	Maximum	Sum	Mean	SD	
Number of PICS used	300	1.00	15.00	692.00	2.3067	2.58746	15.4409***
Amount of stored maize (Qt)	300	1.00	15.00	692.00	2.3067	2.58746	15.4409***

Source: Own Computation (2018)

N = Number of Respondents SD = Standard Deviation

Socio-economic characteristics

Out of the sampled respondents (450), the respondents from the user stratum (300) is composed of 18 (6%) FHHs and 282 (94%) MHHs, whereas the non-user stratum (150) composed of 15 (10%) FHHs and 185 (90%) MHHs. However, there is no mean significant difference (= 2.3545) between users and non-users at less than 10% probability level (Table 10). Another important variable under this category is the educational level of sample respondents that presented in Table 10 shows that 19% of users and 35.3% of non-users are illiterate, while 81% of users and 64.7% of non-users are literate. The result showed that there is a significant mean difference (= 14.4445) between users and non-users in terms of the educational level at less than 1% significance level. The poor educational background of non-users affects their utilization of HS techniques negatively. Because a farmer with better education status has a capability to understand and interpret easily the information transferred to them from DAs and other extension workers. Similarly, lack of education and poor awareness level may be a bottleneck to utilize the extension service delivered appropriately. This could be revealed that illiteracy prohibit the involvement of HHs in receiving the components of modern maize storage package or services.

The mean age of the total sample respondents is 43.90 years and the result of t-test indicated that there is no statistically significant difference between the mean age of users and non-users (Table 11). Moreover, the average household size of users and non-users was found to be 5.7 and 5.6 respectively. However, independent sample t-test indicated no significant mean differences between the two categories at 10% probability level (Table 11). According to CSA (2007), the average household size for ANRS and West Gojjam Zone is about 4.5 and 4.4

persons per household, respectively. The respondent€s average household size (5.65) is slightly higher than the rural average household size of the Zone and the region which indicates the sample households are somewhat surprized by population growth.

Land is the primary source of livelihood for all rural households. The size of the land reflects ownership of an important farm asset. The larger farm size implies more resources and greater capacity to invest in the farm and increased production. However, a noticeable gap exists in entitlement to this important resource between non-users and users. The processes through which land was obtained and the size of the land differed from household to household (ANRSBoA, 2016). Nevertheless, almost all HHs had access to land even if the portion of land acquired by users were small in relation to non-users. According to the information obtained from FGDs, in the study area, households acquire farming land through transfer from government, inheritance and renting. The average mean private land holding size of users and non-users was 1.68 ha and 1.92 ha respectively. There is a statistically significant mean difference (t= 2.56) on private land holding size between users and non-users at less than 1% level of significance (Table 11). This result somehow indicates that the private land holding size is low with relative to the average household size per household. Thus these differences on respondent€s land holding size can affect the status of modern storage techniques utilization.

Farm income is an important economic variable which should be considered in any research particularly the utilization of agricultural extension services. For the purpose of this study, only annual crop income is taking under consideration which has a special influence on using modern storage techniques. Based on this, the mean annual crop income of modern storage users and non-users are 54562.36 ETB and 24331.43 ETB respectively. The variations of annual crop income are higher on non-user groups (SD= 36438.42) with relative to their income extent. The inferential result also shows a mean significant difference (t= 7.85) among the two groups at less than 1% significance level (Table 11). Though the users have lower own land holding size than non-users, the higher crop income is from higher coverage of Pepper and others. The higher annual crop income of users probably allows them to purchase more modern storage techniques and utilize better.

Table 10. Distributions of HHs based on their categorical socio-economic characteristics

Variables	Category	HHs Category (N=450)						
		User (N=300)		Non User (N=150)		Total (N=450)		
		Frequency	%	Frequency	%	Frequency	%	-value
HHs type	FHHs	18	6	15	10	33	7.3	2.3545NS
	MHHs	282	94	135	90	417	92.7	
Educational status	Illiterate	57	19	53	35.3	110	24.4	14.4445***
	Literate	243	81	97	64.7	340	75.6	

Table 11. Distributions of HHs based on their continuous socio-economic characteristics

Variables	HHs Category (N=450)			"
	User (N=300)	Non User (N=150)	Total (N=450)	
	Mean (SD)	Mean (SD)	Mean (SD)	
Age (Years)	44.01(8.80)	43.66(10.08)	43.90(9.23)	-0.375NS
Householdsize (Number)	5.7 (1.8)	5.6 (1.97)	5.65 (1.85)	-0.56NS
Own land holding size (Ha)	1.68(0.92)	1.92(0.98)	1.76(0.95)	2.56***
Annual crop income (ETB)	54562.36(39512.46)	24331.43(36438.42)	44485.39(41034.4)	-7.85***
Annual maize yield (Qt)	45.95(26.51)	45.90(33.71)	45.94(29.10)	-0.017NS
Livestock holding (TLU)	6.01(3.00)	5.25(2.5)	5.76(2.86)	-2.67***
Non-food items expenditure (ETB)	27593.41(24867.31)	28635.2(23150.10)	27940.67(24287.53)	0.43NS
Farming experience (Years)	25.03(9.76)	22.93(9.97)	24.33(9.87)	-2.14*
Cooperative membership status (Years)	15.06(9.73)	12.31(6.89)	14.14(8.97)	-3.0987***

Source: Own Computation (2018)

Where: *, *** = Significant at less than 10% and 1% probability level respectively NS= Not Significant
N= Number of respondents HHs= Household heads (%) = Percent SD= Standard Deviation

The annual maize yield is an important variable which influences their decision to use modern storage techniques so that an assessment was made and results displayed in Table 11. The users' groups had gained an average of 45.95 Qt with a standard deviation of 26.51, while the non-users obtained 45.90 Qt with a standard deviation of 33.71. Though both groups have almost the same annual maize yield, there is a great variation in the non-users group. However, there is no significant mean difference (t=-0.017) between the two groups. Generally, the sample respondents gain 45.94 Qt of maize yield annually.

Empirical studies confirmed that livestock is an important source of cash income in rural areas, which are used for purchasing different types of packages (Elias & Karippai, 2014; Tenna, 2015; Tenna Alemu, 2016b). Table 11 result clearly shows that on average a HHs had 5.76 TLU (6.01 for users and 5.25 for non-users) with a standard deviation of 2.86 (3.00 for users and 2.5 for non-users). There was a significant mean difference (t = -2.67) at less than 1% level of significance between users and non-users. Farmers who owned more livestock have the capacity to bear risks of using the available extension packages. This variable is also a source of oxen, which are sources to plough their field. This by itself encourages the use of technological packages. So that users in the study area have a better utilization status of modern storage techniques. The possible explanation is farmers having more livestock can get more income from sales of livestock by-product and live animals that increase their capacity to participate in the utilization of modern maize storage techniques.

Households expenditure refers to the income allocated for food consumption and other non-food items such as school fee, health services, agricultural inputs, transportation, etc. Non-food items expenditure would have an influential role to determine HHs decision whether to use modern storage techniques or not so that an assessment was made and results displayed in Table 11. Based on the assessment result, the non-users have higher expenditure (28635.20 ETB with SD of 23150.10) than the user groups (27593.41 with SD of 24867.31). However, there is no significant mean difference (t = 0.43) between the two groups. The more non-food items expenditure would face the HHs income deficits so to purchase modern storage techniques so that their utilization would be questioned.

Based on the survey result (Table 11), HS users have relatively higher farming experience (25.03 years) than the non-users (22.93). The result of inferential statistics also showed that there is a significant mean difference (t = -2.14) between the two groups at less than 10% significance level. The overall mean farming experiences of sampled respondents extend to 24.33 years with a standard deviation of 9.87. The higher farming experience of users would help them to acquire the necessary knowledge and skills about modern storage techniques so that they utilize better.

The maize growers€ cooperative membership experience is the most important household characteristics variable so as to acquire the necessary information and knowledge about modern storage techniques from the cooperative societies for better utilization of agricultural extension services. By considering this premise, the survey result (Table 11) showed that the users and non-users have two extreme different cooperative membership experiences, i.e. 15.06 years and 12.31 years respectively. There is also a significant mean difference (t = -3.0987) between the two groups based on the years of joining cooperative societies at less than 1% significance level. The higher cooperative membership experiences of users would allow them to get better knowledge about modern storage techniques. This result implied the extension workers should focus on rural cooperatives in addition to individual HHs for disseminating modern storage technologies. Moreover, they would have access to credit for getting different agricultural inputs including but not limited to modern storage techniques.

Institutional and communication conditions

Based on the survey result displayed in Table 12, 280 (93.3%) and 148 (98.7%) of the users and non-users demanded agricultural inputs other than modern storage techniques, respectively. As a result, the result of inferential statistics showed that there is a significant mean difference (t = 6.1172) between the two groups on using other agricultural inputs at less than 0.05 probability level. In general, almost all (95.1%) respondents have accessed and utilized other agricultural inputs irrespective of the quality and amount they needed in the study area. The more demand of other agricultural inputs by non-users would make them be challenged by a shortage of income for purchasing modern storage techniques. As a result, their status of using modern maize storage techniques like PICS would be questionable.

Access to extension information about PICS is an important factor for farmers so as to get different information about modern storage techniques. Based on the survey result of Table 12, out of the total respondents (450) only 205 (45.6%) respondents have accessed and utilized services delivered by different media like meetings, demonstrations, extension agents, radio, TV, etc. To illustrate specifically, the user groups have more access and utilization status, i.e. 158 (52.7%), than to their counterparts of non-user groups who have only 47 (31.3%). The remaining 142 (47.3%) and 103 (68.7%) of respondents from users and non-users don't have access and not utilized the services related to modern storage techniques respectively. There is also a significant mean difference (= 18.3494) between the two groups on accessing and utilizing the extension services delivered by media. The result clearly showed the ones who have accessed and utilized the extension services delivered by media would have better information and knowledge about modern storage techniques so that they practiced it better.

Perceptions and values on PICS

Households perception on the prices of modern storage techniques is a prime issue for utilization. Thus, an assessment was made and results were displayed in Table 13. Based on the result, 222 (74%) and 120 (80%) of the respondents from users and non-users group respectively perceived price of PICS too high. Likewise, there were some respondents from users and non-users group, i.e. 59 (19.7%) and 25 (16.7%), respectively, perceived the medium level of PICS. On the contrary, only a few respondents from users (6.3%) and non-users (5.3%) group perceived that the price of PICS is low. In general, the highest proportion of respondents, i.e. 342 (76.0%), perceived PICS had a higher price. However, the results of inferential statistics showed there is no significant mean difference (= 2.6433) between the two groups on the perception of PICS' price. The result simply revealed that the higher proportion of respondents that perceive higher price of PICS from the non-users group would affect their WTP for PICS so that their status of modern storage techniques utilization is expected to be low.

Table 12. Distributions of HHs based on their input demand and access to extension information about PICS

Variables	Category	HHs Category (N=450)						-value
		User (N=300)		Non User (N=150)		Total (N=450)		
		Frequency	%	Frequency	%	Frequency	%	
Other agricultural inputs demand	No	20	6.7	2	1.3	22	4.9	6.1172**
	Yes	280	93.3	148	98.7	428	95.1	
Access to extension information about PICS	No	142	47.3	103	68.7	245	54.4	18.3494***
	Yes	158	52.7	47	31.3	205	45.6	

Source: Own Computation (2018)
Where: **, *** = Significant at less than 5%, 1% probability level respectively (%) = Percent
N= Number of respondents HHs= Household heads

Table 13. Distributions of HHs based on their attributed perceptions and values of PICS

Variables	Category	HHs Category (N=450)						-value
		User (N=300)		Non User (N=150)		Total (N=450)		
		Frequency	%	Frequency	%	Frequency	%	
Perception on the price PICS	Low	19	6.3	5	3.3	24	5.3	2.6433NS
	Medium	59	19.7	25	16.7	84	18.7	
	High	222	74.0	120	80.0	342	76.0	
Perception on the storage capacity of PICS	Low	54	18.0	29	19.3	83	18.4	20.9261***
	Medium	53	17.7	54	36.0	107	23.8	
	High	193	64.3	67	44.7	260	57.8	

Source: Own Computation (2018)
Where: *** = Significant at less than 1% probability level NS= Not Significant
N= Number of respondents HHs= Household heads (%) = Percent

Another important thing which should be considered is the attributed values of respondents on the storage capacity of PICS. This is because maize growers would usually prefer the storage technique with the highest storage capacity from the utility perspective. In line with this, the users' group attributed value on the storage capacity of PICS were high (64.3%), medium (17.7%) and low (18%). Whereas, the non-users' group values were high (57.8%), medium (36%) and low (19.3%). In general, out of the total respondents (450), high attributed value (260) of PICS storage capacity took the highest share, while the low attributed value (83) took the least. Additionally, the results of inferential statistics also showed that there is a significant mean difference (= 20.926) between the two groups on the attributed values of the storage capacity of PICS' price. The higher attributed storage capacity value of PICS from the user group is a clear indicator for the better utilization status of PICS.

4.2.2. Econometric model result

MVP Model was used to identify variables affecting maize growers' decision to use storage techniques. Primarily, according to the MVP model results, the pairwise correlations between the error terms ( ) were statistically significant at less than 1% probability level. This may indicate the complementarity and substitutability characteristics of the maize storage techniques under consideration.

Age of the HHs is an important factor in explaining the use of TSP ($p < 0.05$). More specifically, this is to mean that households headed by older farmers were more likely to use this maize storage technique in the study area. The same research result in Nigeria confirmed the aforementioned finding that a unit increase in farmer's age increased the probability of using local storage by 18.3% ($p = 0.01$) and the plausible reason is for the purpose of self-sustenance and household food security (Adetunji, 2009a).

Sex of the HHs (FHHs) is also another demographic factor which does't have any significant importance to use maize storage techniques. This result confirmed that both, i.e. FHHs and MHHs, farmers have equal capability to use different agricultural technologies if other factors remained constant.

Table 14. MVP model results of factors affecting HHs use of maize storage techniques

Variables	Description	NS	TSP	PICS
AGE	Age of the HHs (Years)	0.015 (0.014)	0.038** (0.018)	-0.0135 (0.0137)
FHHs	Sex of the HHs (1= FHHs, 0= Otherwise)	-0.277 (0.3)	0.116 (0.348)	0.102 (0.251)
ACTIVELAFOR	Active labour force (Number)	-0.093* (0.06)	0.005 (0.077)	0.086 (0.063)
EDUCAT	Educational status (1= Literate 0= Otherwise)	-0.113 (0.169)	-0.042 (0.207)	0.480*** (0.152)
FAREXP	Farming experience (Years)	-0.026** (0.013)	-0.037** (0.017)	0.0224* (0.0126)
COOPME	Cooperative membership stat (Years)	0.0297*** (0.010)	0.006 (0.013)	0.0277** (0.0124)
OWNLAND	Own landholding size (Hectare)	0.086 (0.105)	-0.344** (0.160)	-0.5135*** (0.1144)
LIVH	Livestock holding size (TLU)	0.002 (0.029)	0.051 (0.042)	0.0841*** (0.0309)
ANNCRI	Annual crop income (ETB)	-2.28e-06 (2.42e-06)	-0.000013** (3.27e-06)	0.0000157** (4.76e-06)
MAYLD	Annual maize yield (Qt)	0.0006 (0.003)	0.002 (0.005)	-0.0107*** (0.0033)
NONFOIE	Non-food items expenditure (ETB)	-2.05e-06 (3.92e-06)	0.00003** (9.89e-06)	-0.0000109*** (3.74e-06)
OINPUT	Other agricultural inputs demand (1= Yes, 0= Otherwise)	-0.358 (0.332)	0.2735 (0.434)	-1.3165*** (0.3888)
EXTENSION	Access to extension information about PICS (1= Yes, 0= Otherwise)	0.091 (0.152)	-0.211 (0.188)	0.5362*** (0.15335)
HIGPRIC	Perception on the price of PICS (1= High, 0= Otherwise)	0.353** (0.174)	0.1638 (0.1933)	-0.4268*** (0.1605)
SUPHUPIC	Perception on the PICS storage capacity (1= High, 0= Otherwise)	-0.362** (0.146)	-0.5427*** (0.203)	0.5302*** (0.1434)
CONSTANT		-0.777 (0.530)	0.631 (0.712)	1.149** (0.561)
Wald chi² (45) = 203.11				
Prob > chi² = 0.0000				
N = 450				

Source: Model Computation Result (2018)

Likelihood ratio test of = = = 0 chi²(3) = 23.2862 Prob > chi² = 0.0000

Where: * p < 0.1; ** p < 0.05; *** p < 0.01

The amount of active labour force (ACTIVELAFOR) in a household was a factor which negatively and significantly influences the trends of using NS (p < 0.1). The research result in Nigeria confirmed that a unit increase in farmer's household size reduced the probability of not using semi-modern storage by 18% (p = 0.05) (Adetunji, 2009a).

Educational status (EDUCAT) of the respondents, i.e. literate HHs, is the most important socio-economic factors that affect HHs decision to use maize storage techniques. The model result indicated that the educational status of respondents has a positive significant relationship with the HHs decision to use PICS at less than 1% probability level. This indicated that a literate HHs have the most likely to decide and use PICS than to the illiterate HHs in relative to other storage techniques, i.e. NS and TSP. This result is almost similar with the finding conducted in Nigeria that an additional year of education of a farmer created an increase of 0.11 (P = 0.05) in the use of modern storage techniques (Adetunji, 2009a).

The main HHs characteristic categorized under the socio-economic component is farming experience (FAREXP). This variable is positively associated and significantly affected the HHs decision to use PICS at less than 10% probability level. On the contrary, it affects the use of NS and TSP negatively at less than 5% probability level. This result indicated that the more experienced farmers have the more likelihood to use PICS than the less experienced farmers. This result is almost in lined with the finding conducted in Nigeria that an increase of one year of experience of a farmer created an increase of 0.049 (p = 0.05) in the use of modern storage techniques (Adetunji, 2009a).

Cooperative membership status (COOPME) refers to the HHs years of experience on multi-purpose cooperatives since they joined as a member. It's a continuous explanatory variable that positively and significantly affects HHs decision to use PICS and NS by 0.05 and 0.01 significance level respectively.

The main economic factors for rural HHs to use different agricultural extension services including but not limited to improved maize storage techniques are own land holding size (OWNLAND) other than rented landholding size. Own land holding size has a negative but significant relationship with HHs decision to use PICS and TSP at less than 0.01 and 0.05 significance level respectively. The HHs with more privately owned landholding size have the less likely to use TSP and PICS.

The total livestock holding size (LIVH) of a HHs is also the main economic factor next to OWNLAND in the study area. TLU is very important for not only farming purpose but also the transportation of agricultural products from the farm to home and market place. Thus, it€s positively and significantly associated with HHs decision to use PICS at less than 1% probability level. Other things being constant, the result indicated that the more TLU HHs have, the more likely to use PICS than other storage techniques.

Annual income obtained from the selling of crop (ANNCRI) is used to measure the relative dependence of HHs decision to use PICS and TSP through increasing and decreasing their bargaining power respectively. As expected, annual crop income is significantly affected HHs decision to use PICS at less than 1% probability level, but negatively influences the decision to use TSP at less than 1% probability level when other factors are being held constant.

The yearly based maize yield obtained from the total land allocated for maize (MAYLD) per HHs is an important factor in the study area to determine HHs decision to use PICS. It has a significant but negative relationship with the dependent variable. It decreases the likelihood of using PICS at less than 1% probability level. This surprising result is happened due to the small storage capacity and large space requirement of PICS so that it€s not preferred by HHs who produce large quantities of maize product. Because, most of the storage techniques in SSA were blamed by farmers that have small capacities (Adetunji, 2009a).

The annual expenditures for school fee, health, transportation, etc. (NONFOOE) other than food items are an important factor for HHs decision to use PICS and TSP through decreasing and increasing their bargaining power. As expected, it has a negative and positive significant relationship with the decision to use PICS and TSP at less than 0.01 significance level respectively.

The maize grower farmers’ input demand other than improved maize storage techniques (OINPUT) is an important institutional factor that affects HHs decision to use PICS through compromising the income allocated for expenditure purpose. Based on this assumption, it has a significant but negative relationship with the decision to use PICS at less than 0.01 significance level.

Access to extension information about PICS a communication-related factor that affects HHs decision to use PICS. This indicated that the HHs exposed and utilized the services delivered by to radio, television, printed media, public meeting, extension workers, demonstrations, training, etc. have the more likelihood of getting information about PICS and using it at less than 1% probability level.

Perception on the higher price of PICS (HIGPRIC) is an important factor that assumed to have a significantly negative relationship with the decision to use PICS ($p < 0.01$). As expected, the model result depicted that this variable has negative but significant relationship at less than 0.01 significance level. Indirectly this is to mean that, the probability of exercising NS would increase significantly to less than 5% probability level.

Smallholder farmers attributed value on the higher storage capacity of PICS (SUPHUPIC) is the perception related factor which affects HHs decision to use PICS positively ($p < 0.01$). This referred to mean that the more they valued PICS has higher storage capacity, the better the utilized it. However, it affects significantly but negatively the decision to use TS and NS at less than 1% and 5% probability levels respectively.

4.3. Opportunities and Challenges of Maize Storage Techniques

In spite of the quantitative analysis of maize storage techniques, investigating the qualitative insights would give powerful understanding for the proper utilization of improved maize storage techniques. To do so, qualitative assessment of opportunities and challenges for maize storage techniques is crucial. Thus, detailed FGDs and key informants interview (KII) with Woreda experts, DAs, MHHs and FHHs maize growers, local administrators, etc. were conducted. For the purpose of this study, special attention would pay for modern storage techniques for the reasons of specificity, and future applications. It€s expected that maize growers would have used modern storage techniques so that detailed analysis should have focused on it. Of course, a lot of issues were raised during the discussions, but the main ones were summarized into production and productivity potential, high applications of pesticide, high incidence of storage pests and rodents, etc. as some opportunities for improved maize storage techniques. Moreover, the highest investment cost, low accessibility to modern storage techniques, and lower quality of traditional storage techniques, etc. were also summarized as challenges to adoption of modern storage techniques.

4.3.1. Opportunities of maize storage techniques

Production and productivity: The Woredas€ maize production and productivity potential is the prime opportunity selected by almost all FGDs and KII participants to use PICS. It refers to the total amount of yield ha^{-1} obtained from the Woreda. According to the CSA (2011), Womberma and Bure Woredas are the leading places in maize production. Annually, a significantly higher proportion of land is allocated for maize production, and high maize yield obtained from the two Woredas too. The average maize yield productivity is more than 45 Qt ha^{-1}. Therefore, one can imagine, the economic importance of maize yield which was produced from those two Woredas not only for ANRS but also the country in general. Despite the above facts, a significant amount of yield loss occurred as a result of improper postharvest handling mechanism, of which the loss from storage took the highest share. Therefore, to tackle the aforementioned loss, introducing improved maize storage techniques like PICS would be vital. Of course, the promotion mechanisms should be taken into consideration in order to assure the accessibility of information by smallholder farmers. To sum up the ideas, the aforementioned premises would be considered as a good opportunity for the wider utilization of HS techniques.

High use of pesticides: The highest usage of pesticides for storage pests were the second problems of maize growers in the study area, in turn, it would be the opportunity for the wider adoption of modern storage techniques. Most of the FGD participants agreed that pesticide application is widely dominated practice not only for maize but also for other crops. As the survey result confirmed, most of the respondents were used pesticide. This would have negative influence on human health, the environment, etc. Even, based on the GM analysis, a storage technique which used pesticide was not profitable. As a result, they are understanding the negative effects of pesticide and blaming the inaccessibility of modern storage techniques. This issue, from the researchers' insight, could be a good opportunity for PICS to be widely promoted and used by maize growers.

High incidence of storage pests: The high incidence of storage pests and rodents were also another opportunity for improved maize storage techniques. As confirmed by the survey result and the views of farmers in the FGDs and KII, the incidence of storage pests and rodents were high. They are suffering the damages caused by them. Therefore, they are requesting some modern storage techniques which eliminate the incidence of storage pests and cope up the damages caused by rodents. On this aspect, PICS is the most preferable and this is a good opportunity for wider usage too.

4.3.2. Challenges of maize storage techniques

High investment cost: The highest investment cost of PICS, i.e. on average 42 ETB $PICS^{-1}$, with relative to the purchasing power of ETB and their bargaining power is the major challenge of maize growers in the study area. This cost prohibited them not to use more PICS. According to the survey result, on average a HHs produce 46 Qt $year^{-1}$. This HHs should incur at least 1932 ETB at a time. This is to mean that, by the aforementioned capital, a HHs can buy common bags for 193 Qt of maize on the case of existing storage technique. There is a need to recall also how the perception of PICS price negatively influences HHs decision to use PICS. Of course, they discussed in detail during FGDs that price was not related to their perception gaps rather the purchasing power they have. Thus, one can simply imagine how the initial costs of PICS is a challenge for the wider adoption process.

Lack of access to modern storage techniques: Lack of multiple choices of different modern storage techniques is also another challenge for maize growers. The only modern storage in the study area is PICS. Even its accessibility is very low, which is only distributed by a few local suppliers in a far distance from the farmers' localities. It is supplied in a very limited quantity through limited suppliers. From the utility theory perspective, a consumption basket should be full of multiple choices for a HHs so as to maximize his/her utility. Therefore, farmers were blaming this low accessibility of modern storage techniques despite its higher investment costs.

Low storage capacity: The low storage capacity of PICS, i.e. maximum of 100 kg, is another challenge despite its large surface requirement, and easily attacked by rodents, which was also seen by the survey result (Please Refer Table 8). The aforementioned storage capacity is almost equal to the traditional storage structure currently used by farmers. On this aspect, HHs can simply choose the existing traditional bags with the lowest initial price. Therefore, promoting a PICS which have higher storage capacity than the existing one is scanty.

Lower quality of existing storage techniques: In general, the lower quality of existing storage techniques was the main challenge. Almost all existing structures have the lowest quality on reducing the incidence of storage pests and the damages caused by rodents except PICS. Therefore, advancing the existing storage structures so as to cope up the aforementioned damages would be the main challenge in the study areas.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Storage losses are quite severe which was frequently reported by respondents. The pesticide application for storage was quite frequent and common to reduce storage loss though it recorded the highest financial cost and negative influences on biophysical dimensions. Despite the lowest GM in TSP, it was the most predominant maize storage technique used by smallholder farmers.

Even farmers' utilization status was low due to high initial investment cost and perceptions, e.g. PICS had the prime preference rank relative to other storage techniques. Moreover, it is also primarily selected as a storage technique which has the best general importance in terms of eco-friendly, lower damages by storage pests, higher price during selling time, no requirement of pesticide, etc. Even if TSP is widely used by smallholder farmers, it is the one that coerced them to expense and earn the highest and lowest TVC and GM, respectively. Though most smallholder farmers fear to use PICS due to the highest material costs, it is still the most profitable maize storage technique which has both the highest GM and MRR.

The increment of experiences in cooperatives, perceptions on the higher PICS price and storage capacity more likely influenced HHs decision to sell the maize products immediately, whereas, age, farming experiences, own landholding size, annual crop income, non-food items expenditure and perceptions on the higher PICS storage capacity affected HHs decision to use TSP. Eventually, literate HHs, higher farming experience, earlier cooperative membership trend, more livestock holding size and annual crop income, better access to extension information about PICS and positively perceiving the higher PICS storage capacity, probably increased the use of PICS; whereas the higher amount of own land holding size and non-food items expenditure, other agricultural inputs demand and the lower perceived status that PICS have higher price had the highest likelihood to stacked farmers to use PICS.

5.2. Recommendations

The descriptive analysis result showed that TSP is the predominantly used storage technique at the expenses of farmers high TVC and less GM as a result of huge perception gap about modern storage techniques. Therefore, continual awareness creation training about PHL, negative consequences of pesticide application, modern storage techniques, etc. should be put forth. To do so, designing a special PICS manual or curriculum and inculcating in special education programs like adult education as well as giving more educational lessons about storage for 10 minutes in formal schooling is vital and strongly recommended.

Even if PICS is the most profitable storage technique, farmers were blaming its highest initial investment cost since they cannot afford to use more quantity of PICS at a time. Therefore, it would be better to optimize the investment costs of PICS, i.e. at least reduce by 25%. Moreover, enabling credit access is also scanty, i.e. at least providing PICS by a two-year payable loan, so as to increase farmers purchasing power and utilization status.

Smallholder farmers also questioned that PICS has the same storage capacity with other storage techniques in spite of its costs and wider space requirement. They need a storage technique which has the capacity to store at least 200 kg or more. Therefore, redesigning the current PICS in such a way to have the largest storing volume and supplying to farmers will be remedial for their challenge.

Since livestock holding size was one of the significant assets influencing farmers' decision to use maize storage techniques, intervention to improve livestock sector should be encouraged by empowering farmers to own livestock through the provision of livestock credit. Furthermore, development of improved livestock feed and health service should be paid attention to improve their productivity and to increase farmers' income from livestock so that they can buy modern storage techniques.

Access to extension information about PICS was a significant variable that affects the use of PICS. Therefore, diversified use of media to transfer extension information about PICS for wider accessibility and utilization of PICS is strongly recommended.

Establishing maize producers and marketing cooperatives are essential to encourage farmers to store in a group which allows for large quantity storage and getting a better price, which will stimulate farmers to use modern storage technique like PICS. Moreover, this issue recalls the necessity of extension workers to focus on assisting rural cooperatives besides the individual HHs for the wider adoption of modern storage technologies.

Finally, modern storage techniques challenges are different and vary according to their nature and also they are crosscutting issues. Thus, one organization alone cannot bring sustainable measures unless different organizations and institutions interact together and take the storage loss issues through feeling as a sense of ownership, i.e. mainstreaming. Hence; through the interaction process, the active dialogue approach is a prerequisite for bringing about the recommended change towards the mainstreaming of attention being paid to reduce storage loss through the use of modern storage techniques. This will make it possible for the extension service to become aware of the specific needs and problems of a farmer and to respond adequately in assisting them to find the solution to the problem they face.

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7. APPENDICES

7.1. Interview Schedule

Department of Agricultural Economics
Bahir Dar University
•Economics of Hermetic Storage Technique: The Case of Maize Growers in West Gojjam Zone, Amhara National Regional State, Ethiopia,
Structured Interview Schedule Designed for Collecting Data from Male and Female Headed Household Heads for the Fulfilment of MSc Degree in Agricultural Economics

Instruction for Enumerators

- ðÎ Make brief introduction to each farmer before starting any questions, get introduced to the farmers, (greet them the local way) get his name; tell him yours, the institutions you are working for, and make clear the purpose and objective of your questions.
- ðÎ Please ask each question clearly and patiently until the farmer understands (gets) your point.
- ðÎ Please fill up the questions according to farmers€ replies (do not put own opinion).
- ðÎ Please try not to use technical terms while discussing with farmer and do not forget the local unit.
- ðÎ Use only pencil

NB: THIS INTERVIEW SCHEDULE IS USED ONLY FOR THE ACADEMIC PURPOSE!

Date of Interview:---
Identification Number (Code):---
Name of the Woreda:--
Name of the Peasant Kebele Administration----------------------------
Name of the Village:---
Name of Farmer (Household Head):-------------------------------------
Name and Signature of Enumerator:-------------------------------------
Name and Signature of Researcher:-------------------------------------

THANK YOU FOR YOUR COOPERATION!

I. Household Characteristics

1. Household type: 0. FHH 1. MHH
2. Age: ------------------Year
3. Marital status: 1. Single 2. Married 3. Divorced 4. Widowed 5. Others:-------------

4. Educational level of respondents
   0. Illiterate 1. Read and write (formal education) 2. Primary education 3. Secondary education 4. Tertiary education
5. Family size: Male:-------------; Female:----------------; Total:--------------------
6. Labour availability and use in man equivalent

SN	Age Category	Number			Remark (Major Activities Involved)
		Male	Female	Total	
1	<10 Years				

2	10-14 Years				
3	14-50 Years				
4	>50 Years				
Total					

7. House type: 1. Traditional Grass Made 2. Corrugated Zink Made 3. Building 4. Others
8. Farming Experiences:-------------------- Year
9. Membership Experience in MPCSs:------------------ Year
10. Land holding size and allocation in 2008 EC

SN	Land Allocation	Size (Ha)				Remark
		Own	Rent in	Sharecrop in	Total	
1	Cultivated land (Non-irrigable)					
2	Irrigable land					
3	Grazing land					
4	Forest land					
5	Fruit land					
6	Fallow land					
7	Homestead + Others					
Total						

11. Volume of crops production and income in 2008 EC

SN	Types of Crop	Land Size (Ha)	Yield (Qt.)	Amount Consumed (Qt.)	Amount Sold (Qt.)	Unit Price/Qt. (ETB)	Total Revenue (2008) (ETB)
1							
2							
3							
4							
5							
6							
Total							

12. Volume of livestock productions and income in 2008 EC

SN	Types of Livestock	Amount (Number)	Total Monetary Value (ETB)	Amount Sold Within a Year (2008) (ETB)	Remark
1	Oxen				
2	Cow				
3	Heifer				
4	Calve				
5	Sheep (Adult)				
6	Sheep (Young)				
7	Goat (Adult)				
8	Goat (Young)				
9	Donkey (Adult)				
10	Donkey (Young)				
11	Mule				

12	Horse				
13	Chicken				
14	Beehive				
Total					

13. Do you engage on off-farm and non-farm activities in 2008 EC? 0. No 1. Yes
14. If Yes, please fill the following table accordingly by putting (×).

SN	Descriptions of Activities	Involvement		Annual Income Obtained on 2008 (ETB)	Remark
		Yes (1)	No (0)		
1	Daily labourer				
2	Selling grass and straw				
3	Firewood or charcoal selling				
4	Rent of land and pack animal				
5	Petty trading				
6	Handy craft				
7	Carpenter				
8	Weaving				
9	Homemade drinks				
10	Selling stone and sand				
11	Remittance				
Total					

15. Volume of annual expenditures (ETB) in 2008 EC

Descriptions of Items		Unit	Total Amount (ETB)	Remark
Food Items				
1.				
2.				
3.				
4.				
Sub-total				
Non-Food Items				
1.				
2.				
3.				
4.				
Sub-total				
Grand Total				

16. Volume of asset value (ETB) in 2008 EC

SN	Descriptions of Items	Unit	Total Amount of Monetary Value (ETB)	Remark
1	House/Building	ETB		
2	Farm Assets	ETB		
3	Crop Value	ETB		

4	Livestock Value	ETB		
5	Land Value	ETB		
6	Non-farm and Off farm Values	ETB		
7				
Total				

II. Farmers Trends on Practicing Maize Storage Techniques

1. What are the most types of Maize storage techniques you frequently used? (Multiple Answers Are Possible)
   1 .----------------------- 3 .-----------------------
   2 .----------------------- 4 .------------------------
2. Have ever experienced any Maize storage damage? 0. No 1. Yes
3. If Yes, what are the causes of the damage? (Multiple Answers Are Possible)
   1 .----------------------- 3 .-----------------------
   2 .----------------------- 4 .-----------------------
4. How do you overcome the problem? (Multiple Answers Are Possible)
   1 .----------------------- 3 .-----------------------
   2 .----------------------- 4 .-----------------------
5. If you have not experienced any Maize storage damage, How? (Multiple Answers Are Possible)
   1 .------------------------ 3 .------------------------
   2 .------------------------ 4 .------------------------
6. Have you heard about PICS? 0. No 1. Yes
7. If Yes, when have you heard for the first time? ------------- Year
8. From whom you heard about PICS? (Multiple Answers Are Possible)
   1 .--------------------- 3 .---------------------
   2 .--------------------- 4 .---------------------
9. When you started using PICS? -------------- Year
10. Why? (Multiple Answers Are Possible)
    1 .------------------------- 3 .-------------------------
    2 .------------------------- 4 .-------------------------
11. Please mention the problems associated with the application of PICS? (Multiple Answers Are Possible)
    1. -------------------------------- 4. --------------------------------
    2. -------------------------------- 5. --------------------------------
    3. -------------------------------- 6. -------------------------------

III. Farmers Preferences on Maize Storage Techniques

1. Which one is the most preferable types of Maize storage technique for you? (Only One Answer is Possible)
2. Why? (Multiple Answers Are Possible)
   1. --------------------------------
   2. --------------------------------
   3. --------------------------------
   4. --------------------------------
   5. --------------------------------

3. Please fill the following table accordingly by putting (x)

SN	Descriptions of Items	Unit	Maize Storage Techniques				Remark
			NS	TS	TS+IN	PICS	
1	When You Started Using Over	Year					
2	Preferred Types						
3	Awareness	No/Yes					
4	Years of Service Value	Year					
5	Minimum Duration of Storage	Month					
6	Maximum Duration of Storage	Month					
7	Initial Cost	L/M/H					
8	Have Enough Access	No/Yes					
9	Needed Insecticide Application	No/Yes					
10	Amount of Insecticide	Liter					
11	Level of Damage by Pest	L/M/H					
12	Harmful Effect on Human Being	No/Yes					
13	Environmentally Friend	No/Yes					
14	Benefit at All	No/Yes					
15	Level of Market Price During Sale	L/M/H					
16							

IV. Economic Costs and Benefits of Maize Storage Techniques

Items	Descriptions of Items	Unit	Existing Maize Storage Techniques				Remark
			NS	TS	TS+IN	PICS	
Amount of Maize Stored		Quintal					
Amount of Maize Soled		Quintal					
Duration of Storage		Month					
Price During Selling Time		ETB					
Dry Weight Loss		%					
Investment/Construction (Sac/Material) Cost		ETB					
Use Value		Year					
Annual Depreciation		%(ETB)					
Chemical Cost		ETB					
Labour Cost		ETB					
Transportation Cost		ETB					
Loading and Unloading		ETB					
Time Cost for Selling		ETB					
Storage Loss (Damage by Pest		Kg					
Costs of Storage Loss		ETB					

V. Institutional Situations

1. Nearby market distance from your home:--------------------Km
2. Nearby MPCSs distance from your home:-------------------- Km

3. Status of membership in local formal and informal institutions?

SN	Types	Status of Involvement			Remark
		Member	Committee Member	Head/CEO	
1	Agricultural Cooperatives				
2	Equib				
3	Mahiber				
4	Debo				
5	Religious Institutions				

4. Did you got the amount of input based on your demand plan in 2008? 0. No 1. Yes
5. If No, Why?---.
6. Did you receive credit in the production year 2008 E.C? 0. No 1. Yes
7. If Yes, Amount:------------------- ETB; Where did you get the loan?--------------------
8. Was the credit adequate to your demand? 0. No 1. Yes
9. If you did not receive credit in the production year 2008 E.C, what was the reason?------
   ----
10. Did you have contact with Development Agents (DAs) in 2008? 0. No 1. Yes
11. If Yes, how many times per month did you contact with DAs?------------
12. What was the extension advice about? (Multiple answers are possible)
13. Do you receive special training on storage techniques? 0. No 1. Yes
14. Explain:--.

VI. Communication Factors

1. Mass media exposure in 2008 EC

SN	Descriptions of Items	Exposure		Frequency of Exposure	Extent of Utilization (L/M/H)	Remark
		No	Yes			
1	Radio					
2	Television					
3	Published Materials					
4	Group Discussion (1:5)					
5	Public Meeting					
6						

VII. Descriptions of Problems and Suggestions

1. What are the problems, you have faced/observed in the existing Maize storage technique?

SN	Descriptions of Problems	Degree of Importance				Remark
		VI (3)	I (2)	LI (1)	NI (0)	
1						
2						
3						
4						
5						

2. What do you suggest to improve the existing Maize storage technique for reducing Maize storage loss?

SN	Descriptions of Suggestions	Degree of Importance				Remark
		VI (3)	I (2)	LI (1)	NI (0)	
1						
2						
3						
4						
5						

Thanks for Your Cooperation!

7.2. Key Informant Interviews/FGDs Checklist

Name:--
Position:--
Woreda:---
PKA: ---

1. What are the most types of Maize storage techniques practiced in your locality?
2. How do you see the severity of Maize storage loss in your locality?
3. How do you cope up the severity of Maize storage loss?
4. How do you evaluate the performance of the existing Maize storage techniques practiced in your locality on reducing storage damage?
5. What are the most prevalence types of storage pests in your locality?
6. How do you see the extent of pesticide application for protecting storage pests?
7. What are the major types of pesticide practiced by farmers in your locality?
8. How do you see the merits of Hermetic (PICS) storage techniques on reducing storage loss?
9. How do you see the merits of Hermetic (PICS) storage techniques on reducing pesticide application?
10. What are the major existing problems on using appropriate Maize storage techniques?
11. What are the suggestions to improve the existing Maize storage techniques for reducing storage losses?

8. BIOGRAPHICAL SKETCH

The author was born in 1987 in Achefer district of Amhara National Regional State, Ethiopia. After the completion of high school, he has joined Agarfa ATVET College and graduate with a Diploma in Plant Sciences in 2006. Soon after graduation, he has been worked as a development agent worker in Meshenti, Bahir Dar Town Administration Department of Agriculture since 2009. In the meantime, he was joined Bahir Dar University to continue his study and graduated with BSc degree in Rural Development in 2010. After that, he had worked in Bure Agricultural, Technical, Vocational, Educational and Training (ATVET) College as an instructor and other administrative positions since 2010. While he was worked in Bure, he joined Haramaya University to upgrade himself and graduated with MSc degree in Rural Development in 2013. Soon after, he was joined in Bahir Dar University as a lecturer; latterly promoted to assistant professor and working in different positions till now. Currently, he is a graduate student at Tottori University, Japan.