

# Factors Affecting Adoption Of Hermetic Bags Technology Among Smallholder Farmers In Busia County, Kenya

Vitalis Kipngetich Rono

Masters Thesis, Masinde Muliro University of Technology,  
Kenya, Department Of Agriculture Extension and  
Agribusiness

Dr. Vitalis Ogema

Dr. Alice Chesambu

Supervisors, Masinde Muliro University of Technology,  
Department Of Agriculture Extension and Agribusiness

**Abstract:** *The overall objective of the study was to reduce grain postharvest losses caused by storage pest and enhances food security among small-scale farmers in Busia County, Kenya. Specific objectives were formulated: Determine the extent of use of hermetic bags, Identify social factors affecting adoption, and Establish economic factors affecting adoption of hermetic bags by smallholder farmers. A representative sample of 400 farmers was randomly selected for the survey and primary data was collected using questionnaires, observation checklists and focus group discussions while Secondary data was obtained from journals, government policy documents, publications and internet. Data was coded and analyzed using statistical package for social sciences (SPSS) and results presented. The results showed that 47% of small scale farmers used hermetic bags, due to social- economic factors. The study therefore recommends strengthening of dissemination of agricultural technologies to the farmers and subsidize on farm inputs and provision of credits.*

**Keywords:** *Hermetic bags, storage losses, smallholder farmers.*

## I. INTRODUCTION

### A. BACKGROUND

In Sub Sahara Africa (SSA), most Post harvest losses (PHL) occur during harvesting, handling and storage, with (14%) estimated to occur during harvesting on the field (6%), postharvest handling and storage (8%) (FAO, 2011). Post-harvest losses remain a persistent problem in (SSA) and present an enormous threat to food security. One of the key constraints to improving food and nutritional security in Africa is the poor post-harvest management that leads to 20-30% loss of grains, with an estimated monetary value of more than US\$ 2 billion annually and can reach US\$ 4billion (Zorya et al., 2011). Post-harvest losses also remove part of the supply from the market contributing to food price spikes as was experienced between 2008 and 2011 (Rosegrant et al., 2015). Postharvest losses also cause resource wastage because natural resources, human and physical capital are committed

to produce, process, handle and transport food that no one consumes.

Kenya loses 30% to 40% of the total grain output due to inefficiencies in post-harvest handling especially during harvesting and storage (Rembold et al., 2011). Majority of these post-harvest losses are attributed to storage pests like the common weevil and the larger grain borer.

The larger grain borer *Prostephanus truncatus* (Horn), grain weevil *Sitophilus granarius* (L.) and the lesser grain borer *Rhyzopertha dominica* (F.) are some of the predominant food grain storage pests in Africa (Hodges, 2012). Unfortunately, farmers and crop handlers, do not have adequate information on proper crop harvesting and handling methods, resulting in significant damage by insect pests during storage and marketing (Rugumamu, 2009; Kereth et al., 2013).

Apart from causing grain weight losses, incidences of pest attack of the stored grains are also linked to mycotoxin contamination and poisoning. In 2004, for example, one of the largest aflatoxicosis outbreaks occurred in rural Kenya, resulting in 317 cases reported of food poisoning and 125

deaths (Lewis *et al.*, 2005). The two commonly used pest control methods in the grain storage system are fumigation and dilute insecticide dust admixture. Grain fumigation is done at central and medium (grain traders/millers) storage systems where methyl bromide and phosphine are commonly used. The intensification of food production has led to several problems in the post-harvest phase including the major concern of pest infestation during storage (Khalequzzaman and Khanom, 2006). Pest problems have increased side by side with the increase in the quantity of food stockpiled and the longer duration of storage. Such pest problems are more acute in the tropics. Small scale maize farmers, who generally store their grain as whole ears in slatted bins, in rooms, among the rafters of their dwellings, or even in the field, are especially hard hit. The LGB, though, is nearly impervious to simple control measures. The larger grain borer can destroy an entire grain store within five months.

The available grain dusts address pest problems at small farmer level, but the way farmers use them is of concern. The prospect of insects developing resistance to phosphine and grain dusts is real and poses great danger to the grain storage sector.

Traditional storage practices in African countries cannot guarantee protection against major storage pests of staple food crops like maize (FAO, 2008; Gitonga *et al.*, 2013). Lack of suitable storage structures for grain storage and absence of storage management technologies often force the smallholders to sell their produce immediately after harvest. Consequently, farmers receive low market prices for any surplus grain they may produce to avoid post-harvest losses from storage pests and pathogens Kimenju *et al.*, (2009); Tefera *et al.*, (2011). It is therefore, crucial that appropriate, affordable storage technologies are readily available to farmers for them to safely store and maintain quality of their produce Derera *et al.*, (2001). Reducing food losses therefore offers an important pathway of availing food, alleviating poverty, and improving nutrition. Reducing PHL has positive impacts on the environment and climate as it enhances farm-level productivity and reduces the utilization of production resources or expansion into fragile ecosystems to produce food that will be lost and not consumed (Hodges *et al.*, 2011).

## B. STATEMENT OF THE PROBLEM

There has been a high level of wastage in Kenya due to post-harvest losses among smallholder farmers such that losses go up to between 30% to 40 % of the total grain output due to inefficiencies in post-harvest handling especially during harvesting and storage (Rembold *et al.*, 2011). Majority of these post-harvest losses are attributed to storage pests like the common weevil and the larger grain borer (LGB) (Derera *et al.*, 2001). Various storage methods used by farmers have been effective but have limitations, such as chemical control, use of plant products and use of metallic silos. Use of plant products lack standardization and measurement of efficacy (effectiveness). Chemical control methods though effective cause environmental degradation, are hazardous to the users, expensive to most farmers and pest developed resistance to this method as Most small scale farmers cannot administer the right quantities due to low literacy levels (Pereira *et al.*, 2009).

Metallic silos are effective in reducing grain damage and losses from insect pests (Tefera *et al.*, 2011). They are expensive, going for KSh 18,000 (US\$ 210) for a 1ton silo, the smallest size (Simon & Groote, 2010). The cost of the silos is beyond the reach of the smallholder farmers who are resource poor unless subsidized (Simon & Groote, 2010). An attempt has been made to introduce new technology in management of storage pest, hermetic bags but the uptake of this technology has been low. Its acceptance among consumers has generally been low despite stakeholders' efforts promoting the technology for last 4 years in Busia County. There has been no publication on adoption of hermetic bags technology among smallholder farmers in Kenya to identify socio- economic factors affecting adoption and extent of use of hermetic bags. This study will fill the information gap on adoption of hermetic bags technology

## C. RESEARCH OBJECTIVES

The overall objective of the study is to reduce post-harvest losses of grains caused by storage pest and enhance food security among small-scale farmers in Busia County, Kenya

The following specific objectives were formulated.

- ✓ Determine the usage of hermetic bags storage technology by smallholder farmers in Busia County.
- ✓ Identify and describe social factors affecting adoption of hermetic bags storage technology by smallholder farmers in Busia county
- ✓ Identify and discuss economic factors influencing adoption of hermetic bags storage Technology by smallholder cereal farmers in Busia County.

## D. RESEARCH QUESTIONS

The Specific objectives of the study will be guided by the following research questions:

- ✓ What is the extent of use of hermetic bags storage technology by smallholder farmers in Busia County?
- ✓ What are the social factors affecting adoption of hermetic bags storage technology by smallholder cereal farmers in Busia County?
- ✓ What are the economic factors influencing adoption of hermetic bags storage technology by smallholder cereal farmers in Busia County?

## E. JUSTIFICATION

Many people are food insecure in the western region and this food insecurity is partly contributed by storage pest which destroy the cereal grain kept in stores. By controlling post-harvest losses, there will be increased food available without additional resources/inputs. Reduction in post-harvest losses would increase the amount of food available for human consumption and enhance global food security (Trostle, *et al* 2010).

Less Environmental degradation and adverse effects of chemicals pollution will be reduced, when hermetic bags technology is adopted by smallholder farmers.

Small scale farmers will use less input in production as results of cutting down cost of insecticides and using hermetic bags which are re-useable for 3 years leading to increased incomes in the households. This study came up with information on extent of use of hermetic bags and social-economic factors affecting adoption of hermetic bags storage technology among smallholder farmers in Busia County.

Output of the study:

- ✓ Document the current status on use of hermetic storage technology including factors that enhance and those that hinder adoption of the technology and provide policy recommendation.
- ✓ Findings from the study will benefit farmers and Policy makers who will come up with appropriate policies for use in the county.
- ✓ Findings from study will improve academics across the world by increasing reference materials in the libraries,

## F. SCOPE

Study was on extent of use of hermetic bags and social and economic factors affecting adoption of hermetic bags technology among small scale farmers in Busia County.

## II. LITERATURE REVIEW

### A. INTRODUCTION

This chapter dealt with literature related to the study topic. This literature ranged from explaining hermetic technology, to reflecting on its application in bulk storage of cereals grains by farmers in developed economies. Cereal production and postharvest losses in world, Africa and Kenya was reviewed. Principles of hermetic storage technology and transfer of agricultural technologies are discussed. The conceptual frame work of the study was covered in this chapter.

### B. CEREAL PRODUCTION AND POSTHARVEST LOSSES IN WORLD

Crop production contributes significant proportion of typical incomes in certain regions of the world (70 % in Sub-Saharan Africa) and reducing food loss can directly increase the real incomes of the producers (World Bank, 2011). In quantifying the overall ratio of PHL to total production, FAO(2011) considers the losses incurred during each of the five stages from farm to fork, i.e. the losses (1) during harvesting such as from mechanical damage and/or spillage,(2) during postharvest handling, such as drying, winnowing, and storage(insect pests, rodents, rotting),(3)during processing, (4)during distribution and marketing, and(5)during consumption(i.e. good quality food fit for consumption being discarded).Successful markets depend on a consistent supply of better-quality produce and this can be achieved by adopting/adapting improved technologies that also lower PHLs. There are a wide range of such technologies (World Bank 2010), new technologies and approaches can be introduced through innovations systems

and learning alliances (World Bank 2006), but adoption will depend on producers seeing a clear direct or indirect advantage, particularly financial benefit, and potentially on their access to credit. For a sustainable approach to PHL reduction, an intervention has to be planned within the context of the relevant value chain, and more than one type of intervention may be required. Wide ranging reviews of grain postharvest losses have been published by Hodges *et al.* (2010,2013) and Hodges and Stathers ( 2013).

In developing countries most losses of quantity or quality occur, or are at least initiated, at farm level (Hodges *et al.*, 2010). Thus the efficiency of the value chain, on which the livelihoods of producers depends, can be substantially improved if producers can be encouraged to preserve grain quality. A good example is the use of motorized maize Sheller's in Uganda. This maize was of better quality with fewer stones and less broken grain than that produced by manual shelling and as this postharvest handling is quicker it leaves more time to devote to planting the next crop (Hodges et al 2012).

A reduction in food losses also improves food security by increasing the real income for all the consumers (World Bank, 2011). According to estimates provided by the African Postharvest Losses Information System (APHLIS), physical grain losses (prior to processing) can range from 10 to 20 percent. There are wide range of technologies available that, if adopted, would enable smallholders and larger producers to improve the quality and quantity of grains during postharvest handling and storage (World Bank, 2011).

In SSA, most PHL happens during harvesting and post-harvest handling and storage, with for example ,cereal PHL (14%) estimated to occur during harvesting on the field (6%) and postharvest handling and storage (8%)(FAO,2011).

In a study of post-harvest losses of rice from harvesting to milling conducted in Ghana it showed Harvesting losses ranged between 4.07% and 12.05% at farmer's fields. Storage and drying losses were 7.02 and 1.66% respectively (Appiah *et al.*, 2011). As a product moves in the postharvest chain, PHLs may occur from a number of causes, such as from improper handling or bio deterioration by microorganisms, insects, rodents or birds. The issue in LDCs is inefficient postharvest agricultural systems that lead to a loss of food that people would otherwise eat, sell or barter to improve their livelihoods (Hodges *et al.*, 2010).

The current post-harvest system in Ethiopia presents problems of high losses, poor product quality, and limited utilization of the crop. This is associated with the serious unavailability and lack of access to appropriate tools and equipment along with lack of market information about the tools (kalos *et al.*, 2014).The successful implementation of post-harvest technology introduction in Ethiopia will depend on the type of technologies, its accessibility to farmers and the commitment of the government and partner agencies to support the rice promotion in the country (kalos *et al.*, 2014).

At its most basic, any postharvest agricultural supply chain involves the actual harvesting of a crop followed by handling, storage, processing, packaging, transport and marketing.

Postharvest losses do not occur uniformly across the SSA region, but they vary according to different crops, size of farm, weather, and level of mechanization and skill levels of people handling or processing the crop. (Hodges et al 2010).

Data from Aphlis (Table 2.0) also show that losses vary considerably according to the crop grown. Shelling/threshing of maize on small farms can incur a 1.2% loss while the same process will result in a 4% loss on small farms growing sorghum. Storage losses for smallholders growing maize can be as high as 5.3% (but 2.1% for large producers), while small farmers growing millet might experience only a 1.1% loss at this point in the postharvest supply chain.

Causes of losses(%)	Kenya			Uganda		
	Small	Medium	large	Small	Medium	Large
Poor roads	0	5	-	11	6	13
Lackofstorage	6	0	-	18	13	13
Pest	17	18	37	25	32	40
Poor storage	28	14	-	20	16	23
Weather	33	58	50	29	28	10
Spillage	17	5	13	4	6	-
Total	100	100	100	100	100	100

Source: World Bank: 2009.

Table 2.1: Post-harvest losses in small, medium and large scale farms in East Africa

#### C. CEREAL PRODUCTION AND POST-HARVEST LOSSES IN THE KENYA

Cereals production remains a key source of food for a majority of the people in Kenya. The major cereal crops grown in Kenya across all the agro-ecological zones (AEZs) include maize, wheat, rice, sorghum, and millet. Maize is Kenya's main staple food while the other cereal commodities are important food security items. The area under maize cultivation has stabilized at around 1.8 million hectares (ha) (Kangethe, 2011), producing about 3.2 million metric tonnes (MT) per annum (FAOSTAT, 2010) against an estimated consumption of 36 million bags (Kangethe, 2011). Kenya loses 30 to 40 percent of the total grain output due to inefficiencies in post-harvest handling especially during harvesting and storage (Rembold et al., 2011). In spite of the availability of a wide range of storage techniques, significant grain loss occur on-farm in Kenya each year (Komen et al., 2006; Zorya et al., 2011).

In order to reduce the losses incurred after harvesting, farmers take measures such as sufficiently drying maize before storage, using storage structures which are moisture proof and are adequately aired. These include the metal silos, granaries, bags, cribs, baskets or earthen pots. Farmers will also store their cereals in the living houses, which are perceived to be secure as grain losses through theft are minimized. Farmers' use other coping strategies aimed at reducing these post-harvest losses like the use of traditional knowledge which include the use of herbs like the Mexican marigold and hot pepper in storage, selling grain soon after harvest and cleaning or dusting the storage structure with pesticide thoroughly before depositing the maize or acquire the new maize storage technologies (Bett et al 2007). Storage of cereals plays an important role in evening out fluctuations in production from one season or year to the other (Kimenju et al, 2013).

	2009	2010	2011	2012	2013
Cereal(Ha)	2,021,880	2,332,694	2,542,199	2,679,555	2,701,226
Production (Mt)	2,866,388	2,898,900	4,347,437	4,058,581	4,482,694
yield kg/Ha	1,417.7	1,242.7	1,710.7	1,514.6	1,659.5

Source: FAO(2014).

Table 2.2: Cereals production and area under cereal production in Kenya

#### D. HERMETIC STORAGE TECHNOLOGY

Hermetic storage is the process by which oxygen is depleted and replaced by carbon dioxide, thus controlling grain storage pests without use of insecticide. A variety of storage types – from clay pots, to plastic bottles, to specially designed plastic bags, to metal silos – can achieve a hermetic seal with varying levels of effectiveness and cost per unit of seed/grain stored.

Hermetic storage technology consists of enclosing seed in air-tight containers that prevent or minimize gas exchange. Insect aerobic respiration depletes O<sub>2</sub> and increases CO<sub>2</sub>. Insect feeding ceases, and therefore insects begin dying (Murdock et al., 2012).

These technologies are increasingly available in developing countries, and can provide a sustainable and affordable solution to the prevention and reduction of post-harvest loss, and thus increase global food and nutrition security (Maier et al, 2014). For medium scale grain storage, silo bags which were originally developed for anaerobic storage of chopped forages, have been adapted for bulk grain storage first in Argentina in the early 2000s and from there adopted into many countries around the world (Bartosik et al. 2013).

While it has been shown that low oxygen environments can prevent the proliferation of certain species of fungi present in grain (Adler et al. 2000), trials with damp grain stored in silo bags showed that fungi develop to the detriment of grain quality (Castellari,2010). Producers who lack the capital or credit necessary to obtain permanent bulk grain storage and handling equipment are often forced to sell grain at low prices.

##### a. RECENT HERMETIC TECHNOLOGIES

The need for technologies that are effective, affordable and safe for humans and the environment led to the development of the super grain bag and the metal silo technologies.

##### b. METALLIC SILOS

Since 2009, CIMMYT has been promoting the metal silo technology which is said to have the potential of significantly reducing post-harvest losses in maize during storage. There is very little evidence that these technologies have been subjected to economic analysis before being promoted (Kimenju et al, 2010). De Groote et al. (2013) demonstrated that metal silos were effective in controlling maize weevils and the larger grain borer without the use of pesticides such as Actellic Super and Phostoxin.

### c. HERMETIC BAGS STORAGE TECHNOLOGY

Hermetic bags are fairly affordable, costing KSh 250 (US\$ 3) for a bag with a 100 kg capacity. There are two brands being marketed in Africa by different companies. Purdue Improved Crop Storage (PICS bags™) and SuperGrainBag™. PICS bag is a simple, low-cost triple bagging technology originally developed for postharvest storage of cowpea but had been evaluated for applicability to maize storage mainly in West Africa (Murdocket al, 2014). The three layers include an outer polypropylene bag and two inner linings of high density polyethylene (HDPE). Purdue University introduced its PICS bag to the Kenyan market in partnership with local distributor Bell Industry Ltd. Purdue sold over 46,699 PICS bags in Kenya, providing thousands of smallholder farmers across the country access to technology to reduce their postharvest losses by as much as 40 percent (feed the future, 2014).

PICS bag can lead to lower pesticides usage, higher quality and quantity of stored grain, and access to higher market prices. It should be noted that the average life span of the PICS bags is 2–3 years, which means that they must be replaced more frequently than most local containers. Hence, supply chain management becomes paramount to increase the availability of cost effective options for small producers. Concerning hermetic pigeon pea seed storage, Vales et al. (2013) compared storage in PICS and gunny sacks.

There is a reported 1% bruchid infestation with PICS compared to 17% infestation in gunny sacks. They also report 88% germination in PICS compared to 69% in gunny sacks and increased seedling vigor in PICS, measured as increased length of the seedling radicle and Plumule.

Trials have shown that PICS bags can be used for maize storage even in areas with high prevalence of larger grain borer, but storage of maize should begin soon after harvest and drying (Baoua et al., 2014).

The second brand, Super Grain Bag™ is produced by Grain Pro Inc. in the Philippines. Their bags are commercially available in Kenya and though the market is not fully developed since the technology is still new and the awareness levels are still low. Their bag consists of an outer polypropylene bag with an inner high density polyethylene (HDPE) lining. Farmers have the option of buying only the inner lining from Grainpro and using it with their normal bags since the inner lining is the tool that maintains air tightness while in storage. The Super Grain Bags were tested on station and were effective (De Groote et al., 2013).

Hermetic storage increasingly is accepted as the standard for safe, multi-month preservation of high value crops such as seeds, cocoa and coffee (Baributsa et al. 2010). Hermetic storage provides a modern, sustainable, chemical-free, transportable, user-friendly, “green” and cost effective solution to six previously difficult storage problems: 1) Protecting crops from insect infestation; 2) Preventing aflatoxin growth; 3) Preventing rancidity in commodities; 4) Providing safe, long-term storage; 5) Eliminating the need for pesticides, fumigants or refrigeration in storage; and 6) Protecting seed germination for up to a year.



Plate 2.0: Maize Free from weevils which had been kept for one year in Hermetic bag in Dr. Mayabi's store in Kingandole ward in Butula Sub County (Source. Author 2015)

### E. TECHNOLOGY TRANSFER

Technology transfers do not happen spontaneously. Some information is tacit, and requires interpersonal contact to be transmitted. Therefore, being aware of the technology and being able to adapt requires effective contacts between suppliers and users. Therefore, the diffusion of tacit knowledge and their absorption would rely on effective interpersonal interactions. The main ones are: the face to face relationship (Berliant et al, 2001). Three factors are likely to improve these interactions between supply and demand. Firstly, Information and Communication Technologies ease interpersonal relationship and they give a better access to information, thus facilitating awareness about the new technology. Secondly, information and technology flows are favored by vertical and horizontal integration of the market.

#### a. TECHNOLOGY ADOPTION

Adoption of a technology may be measured by “both the timing and extent of new technology utilization by individuals” (Sunding & Zilberman 2001). Diffusion, in turn, is defined as “the process in which an innovation is communicated through certain channels over time among the members of a social system” (Rogers 2003). It is also important to note that the adoption process is a dynamic one, not only in terms of the diffusion of new technologies over time and space, but also from the perspective of the individual farmer. As a result, the willingness and ability to adopt new technologies, the relative weight of the influencing factors and the associated needs for support may change over time. Information from external sources, such as agricultural extension agents, m-services, radio, TV or newspapers, can play a central role in the assessment of suitability and risk of a technology. A study of maize adoption in Tanzania, for instance, showed that high intensity of extension services was one of the major factors positively influencing the adoption of improved seeds (Kaliba et al. 2000). In the case of smallholder farmers, limited access to credit may provide an important constraint to technology adoption as lenders may be unwilling to bear the high transaction costs of small disbursements (Poulton et al. 2006).

## F. FACTORS AFFECTING ADOPTION OF TECHNOLOGY

A number of studies, conducted in various parts of Nigeria suggest some factors (constraints) that are responsible for low level of agricultural technology adoption (Idrisa *et al.*, 2012). In Nigeria, empirical studies on agricultural technology adoption suggest that factors such as socio-economic characteristics of farmers, access to credit or cash resources and information from extension and other media influence adoption rate of new agricultural technology among farmers (Ayinde *et al.*, 2010; Idrisa *et al.* 2012). For example, Ayinde *et al.* (2010) found that education level of farmers; farming experience; farm size; access to extension agents and access to credit have significant and positive influence on adoption. In the study conducted by Kudi *et al.* (2011), farmers' awareness has considerable influence on the rate of adoption of agricultural innovation.

Adoption of improved agricultural technologies has been associated with: higher earnings and lower poverty (Kassie *et al.*, 2011). Literature on agriculture highlights two major drivers of successful agricultural technology adoption in developing countries: (i) the availability and affordability of technologies; and (ii) farmer expectations that adoption will remain profitable—both which determine the extent to which farmers are risk averse (Foster and Rosenzweig, 2010; Carletto *et al.*, 2007). A number of factors drive the above expectations, ranging from availability and size of land, family labour, prices and profitability of agricultural enterprises, and peer effects. The conceptual framework presented here highlights the various pathways through which different factors influence household decisions to adopt agricultural technologies.

One of the most highlighted constraints to agricultural technology adoption is the availability of cultivable land (de Janvry *et al.*, 2011). It is argued that availability of land helps reduce the liquidity constraints faced by households and also reduces risk aversion. On the other hand, ownership of large tracts of land can facilitate experimentation with new agricultural technologies, and also determine the pace of adoption as large land owners are more likely to be the early adopters (de Janvry *et al.*, 2011).

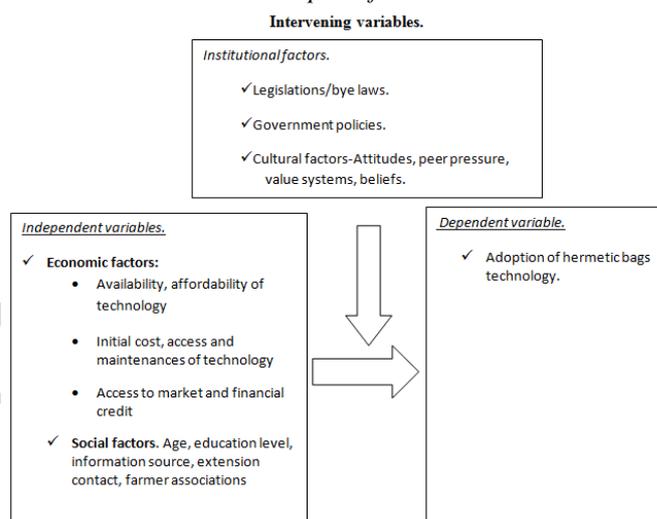
A key determinant of sustained adoption is the profitability of agricultural enterprises. The changing prices for agricultural products are shown to be a major factor in agricultural technology adoption (Kijima *et al.*, 2011). Initially attracted by higher product prices, farmers can abandon the technologies if the expected benefits from adoption are lower than the prevailing costs.

Another reason highlighted in the literature, which drives agricultural technology adoption, is peer effects or learning from other farmers. Evidence from empirical studies on Africa confirm that farmers in Sub-Saharan Africa (SSA) face a host of constraints, ranging from infrastructure, incentives, and liquidity, which impedes adoption and retention of agricultural technology (Kijima *et al.*, 2011).

## G. CONCEPTUAL FRAMEWORK

This study was guided by a conceptual framework that represents the relationship among the variables used in the study. The independent variables have relationship among themselves hence influence each other. The dependant variable was adoption of hermetic bags storage technology while independent variables were social and economic factors affecting adoption of hermetic bags. The technological factors independently or interdependently influence the adoption. Farmers adopting hermetic bags were captured as per their gender, age, literacy level, income status and distance from the inputs markets among other socio-economic factors. The intervening variables are infrastructure factors and cultural factors such as attitudes, farmer to farmer (peer) pressure, beliefs and value systems affects awareness, environmental factors and political factors.

### Conceptual framework



Source: Author (2016)

Figure 2.1: Conceptual framework

## III. MATERIALS AND METHODS

### A. INTRODUCTION

This chapter presents the procedures used in the study under the following subsections; description of the study site, study population, research design, sampling procedures, reliability and validity, data collection, data analysis and presentation, assumptions of the study, limitations of the study and ethical considerations.

### B. DESCRIPTION OF THE STUDY SITE

Busia County is located in Western Kenya and covers an area of 1661 km<sup>2</sup>.

The county borders Lake Victoria to the South West, the Republic of Uganda to the West, North and North East; Bungoma and Kakamega Counties to the East and Siaya County to the South and South East. It is located between longitude 33° 55' and 34° 25' East and latitudes 0° 30' and 0° 45' North.

Administratively Busia County consists of 7 sub counties namely, Butula, matayos, Nambale, Samia, Teso North and Teso South. There are a total of 60 locations and 121 sub locations. Busia County falls within the Lake Victoria Basin and has an altitude ranging from 1,130m on the lake's shore to 1,375m above sea level in central part of the county. The dominant agro-ecological zone is Low Midlands (LM) with about four distinct subzones that support different agricultural activities. These subzones are; LM1, LM2, LM3 and LM4 which represent sugarcane, marginal sugarcane, cotton and marginal cotton zones. The County of Busia has a population of 743,946 (2009) and a population density of 439 people per km<sup>2</sup>. Women comprise about 52.1% (387,824) of the total population while men comprise 47.9% (356,122) with an annual population growth rate of 2.9%. The county has a total of 154,225 households with an average size of 5 persons per household.

The county has a bimodal rainfall pattern with the long rains falling between March and May while the short rains fall between August and October. The county receives rainfall of between 1270mm to 1790mm and an annual mean of 1500mm. The temperature ranges from a minimum of 26<sup>0</sup>C to a maximum of 30<sup>0</sup>C. Due to its proximity to Lake Victoria, the county experiences high humidity as a result of high rates of evaporation (1800mm to 2000mm per year). The county economy is heavily reliant on fishing and agriculture, with cassava, millet, sorghum, rice sweet potatoes, beans, and maize being the principal cash crops.

Butula sub county is purposively selected as study site as various annual food and crop situations reports indicated high post-harvest grain losses in the sub county and most grain farmers in the sub county are smallholder farmers, with land holding of 2.0 acres (M.O.A, 2011,2012). Butula sub County has a population of 121,870 persons (57,025 males and 64,845 females) and with population density of 493 persons per km<sup>2</sup>. Butula Sub County has land surface area of 247.1km<sup>2</sup> and it is administratively sub divided into six locations/wards with 21 sub locations.

Subcounty	Male	Female	Total	No. HHs	Land (sq.km)	Density. (km2)
Busia	356,122	387,824	743,946	154,225	16795.0	439
Teso South	66,629	71,295	137,924	27,372	299.6	460
Matayos	156,090	171,762	327,852	68,781	681.0	481
Nambale	99,065	106,917	205,982	42,828	433.9	475
Butula	57,025	64,845	121,870	25,953	247.1	493

Source: (KNBS, 2009).

Table 3.1: Population densities of Sub-County in Busia County

Wards	Land (sq.km)	No. HHs	male	female	Total population.
Kingandole	36	4,323	8,270	10,000	18,270
Marachi central	39	4,325	8,616	11,200	19,816
Elugulu.	42	4,325	9,454	10,200	19,654
Marachi East	44	4,325	10,600	11,265	21,865
Marachi west	36	4,230	10,011	11,200	21,211
Marachi North	50.1	4,425	10,004	11,050	21,054
Butula	247.1	25,953	57,025	64,845	121,870

Source: KNBS,(2009)

Table 3.2: Population and land sizes in wards in Butula Sub County

### C. TARGET POPULATION

The target population were smallholder grain farmers exposed to technology in Busia County and will be primary beneficiaries of the findings of the study. The accessible population 121,870 consisting of (57,025 males, 64,845 females) and 25,953 farm households in Butula sub county (KNBS 2009).

### D. RESEARCH DESIGN

The study employed evaluation research design. It will seek to establish the degree of relationship between two or more variables, and the interactions of such variables (Orodho, 2003). The study started with pre-testing of questionnaire instrument in one location with similar condition which it was excluded from the main study. The dependent variable was adoption of hermetic bags while independent variables are personal social and economic factors affecting adoption, while intervening variables were institutional such as roads, policies and legislations. Evaluation research design was adopted in this study based on the conceptual relationship between the independent variable and the dependent variable. The possible relationships of independent variable in retrospect on dependent variable was analyzed.

Specific objectives	Measurable variable /indicators.
Determine the usage of hermetic bags technology among cereal small holder farmers	Number of Farmers are using hermetic bags Number of Bags purchased. Duration of using hermetic bags. Number of re-use times for the hermetic bags.
Identify and describe the social factors affecting adoption of hermetic bags by smallholder farmers	Awareness among farmers. Education levels of farmers Farmers Age Gender Farming experience Training received. Labour availability Information source utilization
Identify Economic factors influencing adoption hermetic bags technology among smallholder farmers	Inputs availability. Land ownership Farm size. Credit sources Distance to market. Initial Cost of hermetic bags.

Table 3.3: Summary table of specific objective and measurable indication

### E. POPULATION OF STUDY

The target population comprised of smallholder farmers in Butula sub-County, whose population was projected at 121,870 persons, with 25,953 households (KNBS 2016). For

the purposes of this research, household head was adopted as a unit.

F. SAMPLING PROCEDURE

Stratified random sampling technique was adopted. Stratified sampling enhances representativeness in studies that involves sub groups of respondents (Frank et al 2002). A simple random sampling technique was employed to select 4 wards (locations) out of the six wards in the sub county. Four Hundred farmers were randomly selected from the sub county.

Wards	Land (sq.km)	No. HHs	male	female	Total population.	Sample size
Marachi central	39	4,325	8,616	11,200	19,816	96
Elugulu.	42	4,325	9,454	10,200	19,654	96
Marachi East	44	4,325	10,600	11,265	21,865	106
Marachi North	50.1	4,425	10,004	11,050	21,054	102
<b>Totals.</b>	<b>175.1</b>	<b>21,725</b>	<b>38674</b>	<b>43,715</b>	<b>82,389</b>	<b>400</b>

Table 3.4: Population and sample sizes in four wards, Butula Sub County

a. SAMPLE SIZE DETERMINATION

To establish the estimation of desired sample size of farmers for multistage random sampling, the rule of thumb was to obtain as large sample as possible. The following fisher formula (Mugenda, 2008) was used to determine the sample size

$$n = Z^2 pq / d^2 \text{ -----equation 3.1}$$

Where n=the desired sample size

Z=the standard normal deviation at 95% confidence level=1.96

P=the proportion in the target population estimated to have characteristics being measured.

q=1-p

d=the level of statistical significance set at 0.05%

Since the sample size was larger (greater than 30) in this study, the values z is 1.96 at 95% confidence interval. Therefore by taking the proportion of a target population with a certain characteristic as 0.50 and the z-statistic as 1.96 with the desired accuracy at the 0.05 level, then the sample size of farmers is:

$$n = (1.96)^2(0.50)(0.05)/(0.05)^2 = 384.16 \text{ farmers}$$

However sample of 400 farmers was adapted to hedge against loss of respondents from voluntary withdrawal or non-response.

Study population	Sampling method	Sample size
Farmers	Random sampling	400
FGD-local leaders, religious, opinion leaders, extension agents	Representative sampling	12
Observations	purposive	10

Table 3.5: Summary for sampling methods for each study population unit and their size

G. DATA COLLECTION

The intention of the research, goals and expected outcomes was stated clearly to guard against raising wrong expectations from respondents. Both Primary and secondary data gathering procedures was used.

a. PRIMARY DATA

Collection of data was preceded by developing the data collection instruments and training of two research assistants so that they could fully understand the context of the study and any underlying issues. Pre-tested, close ended questionnaires was used, observation checklists, structured interviews and focus group discussions. Primary data was obtained from respondents. There are several methods to be used to yield primary data during field visits. Therefore, for these study the methods to be used are interview guides/administering questionnaires; focus group discussions and observations checklists (Table 3.2).

✓ Interview guide: A method of data collection that involved researchers seeking both open-ended and closed ended answers related to a number of questions, topics or themes. Personal interviews to cereal farmers (Appendix) to get accurate data on intervening factors influencing adoption of hermetic bags in Busia county. This assisted in getting information from grain farmers who may not fill out questionnaires due to their education levels.

✓ Questionnaires: Administering questionnaires with open and closed questions to both large scale and small scale farmers to collect socio-economic data. The questionnaire sought information on use, availability, access, affordability of hermetic bags and access to extension service and credit facilities by farmers. Focus group discussion (FGD): This was used to support the questionnaire and interview schedule. This is an interview with a group of 8 to 12 individuals brought together for a period of usually 2 to 3 hours to explore on any topic during discussion. Selected group members have particular knowledge or interest in the topic and questions are asked of the whole group (Cosby 2004). FGD guide will be used to gather information on hermetic bags technology. This group discussion will include 2 local leaders, 2 agriculture officers, 1 cereal trader, 1 agro-dealer, 3 farmers, 2 religious leaders and 1 teacher.

✓ Direct observation: The researcher together with his field assistants had checklist with which observations will be cross checked and observations will be noted in the note book.

Study population unit.	Sampling method	Sample size	Data collection instrument	Appendix number
Farmers	Random sampling	400	Questionnaire observation checklists	II
FGD-local leaders, religious, opinion leaders, extension agents	Representative sampling	12	Interviews FGD guide	V
Observations	Purposive	10	observations	III

Table 3.6: Summary for the instruments for data collection per each study population

b. SECONDARY DATA

The secondary data was completed. The data was obtained from journals and review papers, Government annual reports and policy documents, and workshop proceedings. Internet was vital resource in accessing relevant online publication. Other secondary sources of data included reports from stakeholders PALWECO, ADS, Elite bags suppliers and Busia county government.

H. RELIABILITY AND VALIDITY OF RESEARCH INSTRUMENTS

A research instrument is reliable if it measures what it purports to measure consistently.

a. VALIDITY

According to Mugenda and Mugenda (2003); validity is the accuracy and meaningfulness of inference based on research outcomes. Therefore, it has to do with how data obtained during study will be accurately representing the study variables. Service providers were involved in pre-testing of research instruments in the location which will not be included in the sample for study. Supervisors from Masinde Muliro University of science (MMUST) will examine the results and recommendations made for adjustment hence validity.

b. RELIABILITY

Refers to the measure of the degree to which a research instrument yields consistent results or data after repeated trials (Mugenda and Mugenda 2003). To ensure reliability of data collection instruments, the questionnaire and observation checklists were pre-tested using a representative sample of respondents. This provided an opportunity to correct biased and/leading questions, ambiguous terminologies and inclusion of respondents concerns.

I. ETHICAL CONSIDERATIONS

Ethics is the standard of conduct and moral judgement. They are basically the principles of the right and wrong, which behaviour is based. Mugenda (2003), defines ethics as the branch of philosophy which deals with one's conduct and serves as guide to one's behaviour. Information gotten from the respondents was kept confidential for protection purposes. The researcher conformed to the principle of voluntary consent where respondents willingly participate in research.

J. LIMITATIONS

In the process of carrying out the study, the following challenges are likely to be encountered;

- ✓ The research was limited to the adoption of hermetic bags technology.

- ✓ The research dealt only with cereal grains farmers, traders and representatives in a FGD

K. ASSUMPTIONS

Based on the proposed study, the following assumptions will be made;

- ✓ Hermetic bags are in use in the sub counties.
- ✓ The respondents were answering the questions objectively hence reliability.
- ✓ Field conditions did not hinder the respondents from giving honest opinions.

L. DATA ANALYSIS AND RESULTS PRESENTATION

Data was coded and roasted for analysis. The statistical package for social science (SPSS 12.0) will be used for analysis. Components to be measured included the mean, variance and standard deviations. Analysis of variance was conducted to establish the contribution of different factors to the responses. Socio-economic factors were analyzed using chi-square to show the relationship between independent variables and dependent variable. Data was presented in form of tables, graphs and charts.

Specific objectives	Measurable variable/indicators	Method of analysis
i) Determine the usage of hermetic bags technology among small holder farmers	Number of farmers using hermetic bags. Number of bags purchased. Length of time using hermetic bags. (Duration). Duration of re-use of hermetic bags.	Descriptive statistics
ii) Identify and describe social factors affecting adoption of hermetic bags among smallholder farmers	Awareness among farmers. Age, Education levels of farmers Farming experience Training received. Attitude Group influence Labour availability Information source utilization.	Descriptive statistics Chi- square
iii) Establish economic factors limiting adoption of hermetic bags	Bags availability Durability of hermetic bags Farm sizes. Credit sources Distance to market.	Chi-square, Descriptive statistics.

Source author: 2015

Table 3.7: Data analysis methods against measureable variables per each specific objective

IV. USAGE OF HERMETIC BAGS TECHNOLOGY AMONG CEREAL SMALL HOLDER FARMERS

A. INTRODUCTION

This chapter presents findings on the usage of hermetic bag technology. The findings were arrived at by determining the number of farmers using hermetic bags, number of bags purchased and duration of use of hermetic bags technology among other variables. The study also looked at socio-demographic characteristics of the respondents.

B. SOCIO-DEMOGRAPHIC CHARACTERISTICS OF THE HOUSEHOLDS

The socio-demographic characteristics of the study had direct impact on this study, in that it helped to understand the economic gain of the respondents, their farming experience, and size of land under cereals farming, land workforce amongst others. Some of the socio-demographic characteristics include age, gender, marital status, and occupation and farming experience. All these are discussed in the following sections.

a. GENDER OF THE RESPONDENTS

Gender was determined from the questionnaire where the respondents were asked to indicate their sex. The results were analysed and the results presented in a pie chart in Figure 4.1 below.

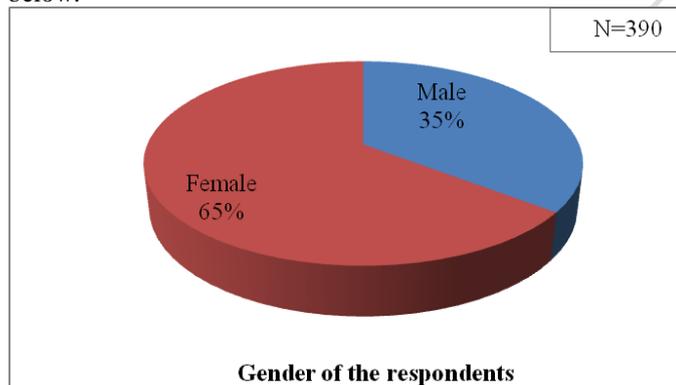


Figure 4.1: Gender distribution of farmers in Butula Sub-county Busia County

Female respondents were more in this study 65% (254), as compared to male 35% (136). This implies that more female respondents were interviewed as compared to male respondents in this study. Those female farmers are the managers of their farms and therefore the main decision makers of farming activities. Being the main decision makers, they tend to be more rigorous in trying out new agricultural innovations unless when economic constraints restrain their efforts. (Mbugua, 2009)

Gender relationships with agricultural production and technology adoption have been investigated for a long time. Most show mixed evidence regarding the different roles men and women play in technology adoption. In the most recent studies, Doss and Morris (2001) in their study on factors influencing improved maize technology adoption in Ghana, and Overfield and Fleming (2001) studying coffee production

in Papua New Guinea showed insignificant effects of gender on adoption.

b. AGE DISTRIBUTION OF THE RESPONDENTS

Age of the respondents was determined through the questionnaire where they were required to indicate their ages. The results were analysed and presented in the Figure 4.2 below.

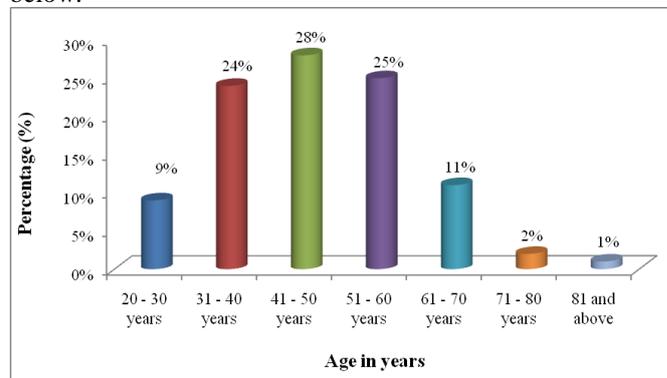


Figure 4.2: Age distribution of farmers in Butula Sub-county in Busia County

The highest age composition of the respondents was between 41-50 years, which was 28% (109), 51- 60 years 25% (98), 61-70 years 11% (43), 20 – 30 years 9% (35). The eldest respondent in this study was above 80 years of age. However, the results concur with Sunding and Zilberman (2001) reported that the tendency to adopt modern technology declines with age. Older farmers operate with shorter time horizons, so investing time and effort in adopting new innovations might not be practical. Younger farmers who operate with longer planning horizons often make a greater effort to acquire the skills or knowledge they need to adopt new technology.

Age is another factor thought to affect adoption. Age is said to be a primary latent characteristic in adoption decisions. However there is contention on the direction of the effect of age on adoption. Age was found to positively influence adoption of sorghum in Burkina Faso (Adesiina and Baidu-Forson, 1995).

In central Kenya, age had a positive effect on adoption. The effect is thought to stem from accumulated knowledge and experience of farming systems obtained from years of observation and experimenting with various technologies. In addition, since adoption pay-offs occur over a long period of time, while costs occur in the earlier phases, age (time) of the farmer can have a profound effect on technology adoption.

However age has also been found to be either negatively correlated with adoption, or not significant in farmers' adoption decisions (Baidu-Forson, 1999). Older farmers, perhaps because of investing several years in a particular practice, may not want to jeopardize investments by trying out a completely new method. In addition, farmers' perception that technology development and the subsequent benefits, require a lot of time to realize, can reduce their interest in the new technology because of farmers' advanced age, and the possibility of not living long enough to enjoy it (Caswell *et al.*, 2001).

c. *SIZE OF THE HOUSEHOLDS*

The size of the household in this study was indicated by the respondents on their questionnaires. The results were analysed and presented in the Figure 4.3 below.

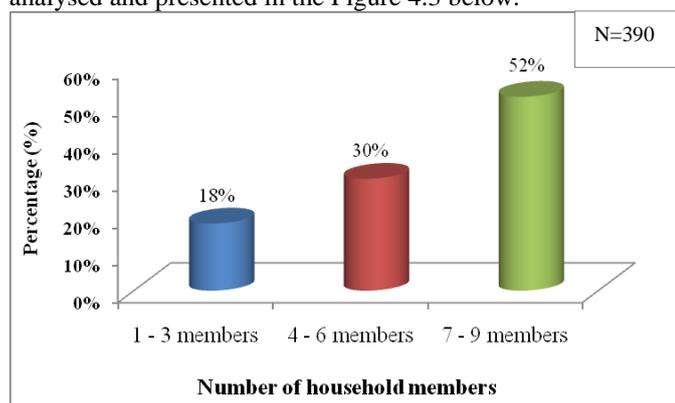


Figure 4.3: Number of household members in Butula Sub-County, Busia County

The results indicate that 52% (203) of the respondents' household consisted of 7 to 9 members, 30% (117) households consisted of 4 to 6 members while households that had 1 to 3 members were 18% (70). These findings are slightly not in agreement with the findings of KNBS (2009) which found that the county has a total of 154,225 households with an average size of 5 persons per household.

B. FINDINGS ON USAGE OF HERMETIC BAGS TECHNOLOGY

The forthcoming section presents findings and discussion on the usage of hermetic bags technology among cereal small holder farmers.

a. *NUMBER OF FARMERS USING HERMETIC BAGS*

The researcher sought to find out the number of farmers using hermetic bags technology for storage of their farm produce. The farmers were asked to indicate whether or not they use hermetic bags for storage. The results were analysed and presented in the Figure 4.4 below.

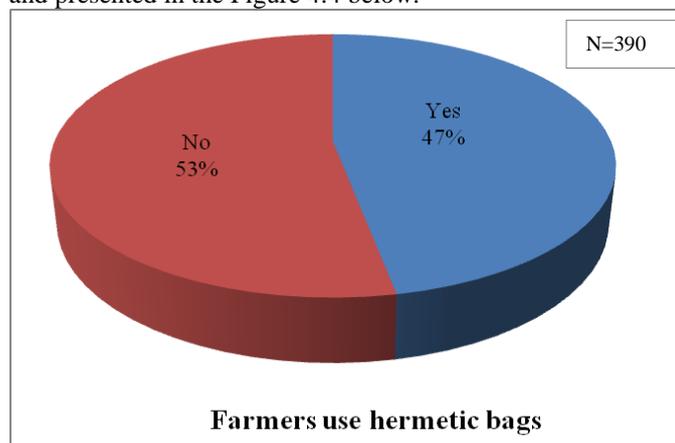


Figure 4.4: Usage of hermetic bags storage technology in Butula Sub-County Busia County

It was found that 47% (183) of the respondents had used hermetic bags technology for storage while 53% (207) had not. A Pearson Chi-Square test of independence conducted value value ( $\chi^2_{1,0.01} = 4.070a$ ) showed that there was no significant ( $P > 0.01$ ) association amongst the farmers who use hermetic bag technology. This meant that more than half of the people in Busia County were not using hermetic bag technology for cereal storage, which may lead to post harvest losses in large quantities. In a study of post-harvest losses of rice from harvesting to milling conducted in Ghana it showed Harvesting losses ranged between 4.07% and 12.05% at farmer's fields. Storage and drying losses were 7.02 and 1.66% respectively (Appiah et al, 2011).

b. *NUMBER OF BAGS PURCHASED*

To determine the extent of use of hermetic bags storage technology by smallholder farmers in Busia County, the researcher sought to look at the number of bags purchased by the time this research was conducted.

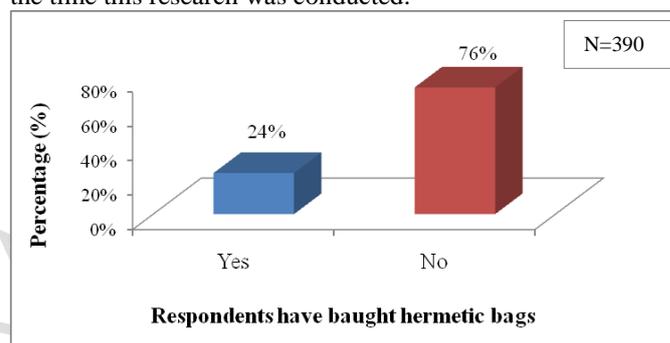


Figure 4.5: Purchase of hermetic bags in Butula Sub-County, Busia County

The findings revealed that 76% (289) respondents had never bought hermetic bags for storage of their cereals, while 24% (101) respondents were reported to have bought the bags. Pearson Chi-Square value ( $\chi^2_{2,0.01} = 255.344a$ ) showed that there was highly significant ( $P < 0.01$ ) variation in the means of storage farmers use. This then meant that farmers in Busia County still used other methods of storage.

However, looking at these other means of storage, the available grain dusts address pest problems at small farmer level, but the way farmers use them is of concern. The prospect of insects developing resistance to phosphine and grain dusts is real and poses great danger to the grain storage sector, while traditional storage practices in African countries cannot guarantee protection against major storage pests of staple food crops like maize (FAO, 2008; Gitonga et al., 2013). Lack of suitable storage structures for grain storage and absence of storage management technologies often force the smallholders to sell their produce immediately after harvest. Consequently, farmers receive low market prices for any surplus grain they may produce to avoid post-harvest losses from storage pests and pathogens Kimenju et al., (2009); Tefera et al., (2011).

*Losses Incurred Due To Lack Of Hermetic Bags*

During this research it was evident that farmers who did not use hermetic bags incurred losses. The researcher sought to find out the type of loss and the causes of these losses.

The Figure 4.6 below shows the results of a correlation analysis.

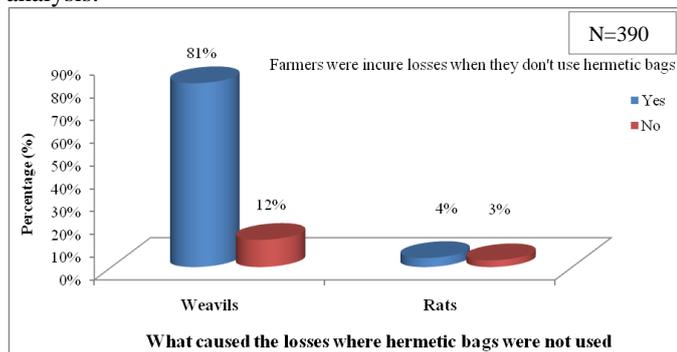


Figure 4.6: causes of cereal losses in Butula Sub-county Busia Kenya

From the Figure 4.6 above, the main causes of damages to the harvests were rats and weavils, with the later causing 81% of the damage to cereals. Pearson Chi-Square value ( $\chi^2_{1,0.01} = 7.096a$ ) showed that there was highly significant ( $P < 0.01$ ) association between the losses farmers incurred due to lack of hermetic bags and the causes of the losses. This implied that farmers who don't use hermetic bags suffer heavy losses due to attacks from weavils and rodents. The results of this study corroborate other on-station findings from West Africa that this is a good storage technology, capable of reducing postharvest loss and therefore improve food security (Baoua et al., 2014, 2012). Unlike previous findings from an on-station trial in Kenya that the hermetic bags can be perforated by postharvest insects (De Groote et al., 2013), the results of this study showed that no inner bag was perforated by insects even after four months of storage.

*c. DURATION OF USING HERMETIC BAGS*

The researcher sought to find out the duration that farmers have used hermetic bags. Farmers were asked to indicate the duration they have stored their grains using hermetic bags.

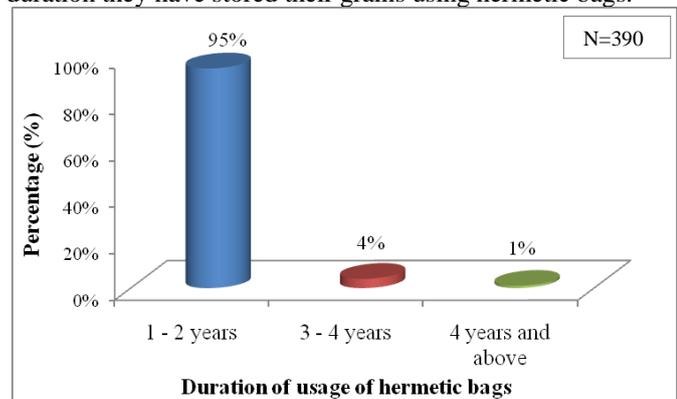


Figure 4.7: Duration of hermetic bags storage technology uses in Butula Sub-County Busia

The results show that 95% (371) of farmers have used hermetic bags for duration between 1 to 2 years, 4% (16)

between 3 to 4 years while only 1% (4) has used hermetic bags for 4 years and above. This indicates that farmers have been lately learnt about hermetic bags. It is evident that for those farmers using hermetic bags started with 1% of but the trend has increased.

The results were cross tabulated to find out the relationship between the duration farmers use to store their grains and if they store in hermetic bags. The Figure 4.8 below shows the results.

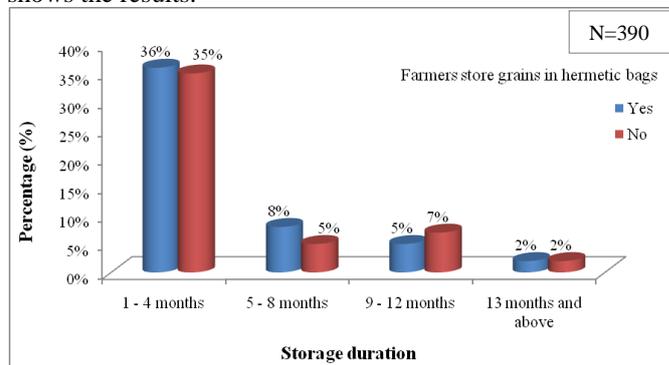


Figure 4.8: Duration of storage of cereals in hermetic bags in Butula Sub-county, Busia County

From the results, 36% (140) of the farmers store grain for only between 1-4 months in hermetic bags. It was found that a small percentage 2% (8) of farmers only store grain for more than a year. It was also found that 35% (137) farmers don't use hermetic bags for storage of grains through the period of 1 - 4 months, and there those 2% (8) who store grains for more than a year but still they don't store in hermetic bags, but use other means of storage. Pearson Chi-Square value ( $\chi^2_{3,0.01} = 1.805a$ ) showed that there was no significant ( $P > 0.01$ ) association between the storage duration and storage of maize in hermetic bags. This means that farmers could store their grains for certain durations regardless of whether they store in hermetic bags or not, as they were other means of storage. Some of these other means were mentioned by farmers and they were analysed, as shown in the Figure 4.9 below.

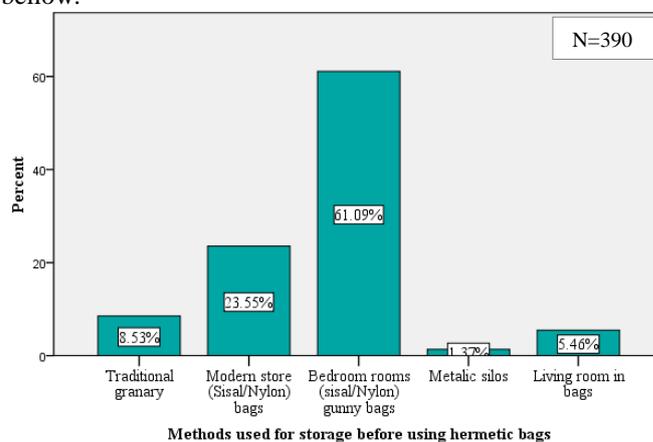


Figure 4.9: Methods used for storage before using hermetic bags in Butula Sub-county Busia County Kenya

The results reveal that farmers who don't use hermetic bags store grains have other means of storage. The results show that 60% (238) keep their maize in bedrooms, in sisal or nylon bags, 24% (94) store in modern stores in sisal or nylon bags while 9% (35).

Hermetic bags are the best option to farmers although there are challenges of adoption as it will be discussed in the forthcoming chapters. Hermetic grain storage systems strive to eliminate all exchange of gases between the inside and the outside of a grain storage container. If the gas exchange is low enough, living organisms such as insects within the container will deplete oxygen and produce carbon dioxide until they die or become inactive due to the low oxygen. Hermetic grain storage can be an appropriate method for many subsistence farmers. It eliminates the need for insecticides, which are costly and often inaccessible for these farmers. Misuse of insecticides by farmers is common and can cause health and environmental problems (Baributsa et al., 2010). If maize is dried to 14% moisture or less, storage fungi can be controlled. A robust container protects the maize from birds and rodents.

Grain losses is a possible factor which can lead to wastage of food, in that farmers cannot even have enough to store for future use before another harvest season. Crop production contributes significant proportion of typical incomes in certain regions of the world (70 % in Sub-Saharan Africa) and reducing food loss can directly increase the real incomes of the producers (World Bank, 2011). In quantifying the overall ratio of PHL to total production, FAO(2011) considers the losses incurred during each of the five stages from farm to fork, i.e. the losses (1) during harvesting such as from mechanical damage and/or spillage,(2) during postharvest handling, such as drying, winnowing, and storage(insect pests, rodents, rotting),(3)during processing, (4)during distribution and marketing, and(5)during consumption(i.e. good quality food fit for consumption being discarded).

**C. SOCIAL FACTORS AFFECTING ADOPTION OF HERMETIC BAGS BY SMALLHOLDER FARMERS**

As much as hermetic bags prove to be the best solution with the most recent storage technology, it has challenges that may hinder its adoption by the farmers in Busia County. The factors affecting the adoption of hermetic bags by farmers are discussed in the forthcoming sections.

**a. AWARENESS AMONG FARMERS**

Adoption of hermetic bags storage technology is very low. The study sought to assess so far how the farmers have received information about hermetic bag storage technology. Farmers were asked to indicate the sources they got the information about hermetic bags storage technology. The results were analysed and presented in the Figure 4.10 Below.

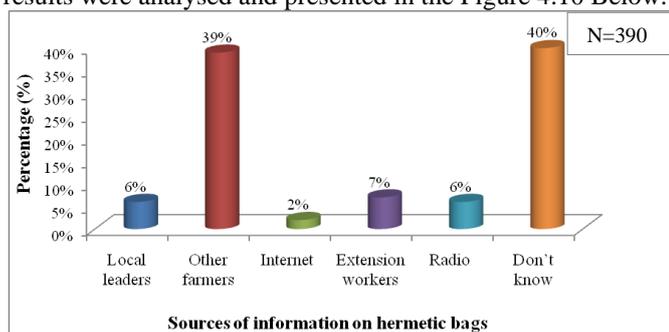


Figure 4.10: Sources of information on hermetic bags in Butula Sub-County Busia County Kenya

The results indicate that 39% (152) got the information from other farmers, 6% (23) got the information from local leader, 2% (8) got the information from the internet while 6% (24) got the information from the radio. However, 47% (183) indicated that they had never heard about hermetic bag storage technology.

In particular, the relatively limited adoption and sustained use of agricultural technologies is partly because of lack of information and that technologies are not readily available in agricultural markets. Sourcing such inputs from distant markets can reduce the profitability and eventual duration of adoption. Promotion of technical change through the generation of agricultural technologies by research and their dissemination to end users plays a critical role in boosting agricultural productivity in developing countries (Mapila et al, 2011). Ayinde et al. (2010) found that education level of farmers; farming experience; farm size; access to extension agents and access to credit have significant and positive influence on adoption. In the study conducted by Kudi et al. (2011), farmers' awareness has considerable influence on the rate of adoption of agricultural innovation.

**b. EDUCATION LEVELS OF FARMERS**

The level of education is a key social factor that that can affect adoption of hermetic bags storage technology. Generally education is thought to create a favorable mental attitude for the acceptance of new practices especially of information-intensive and management-intensive practices (Caswell et al., 2001). Education is thought to reduce the amount of complexity perceived in technology and may increase the likelihood of a technology's adoption, although mixed results in relation to education have been shown in other studies.

Awareness depends on the level of education of a community. The researcher asked the farmers to indicate their level of education. The results were analysed and presented in the Figure 11 below.

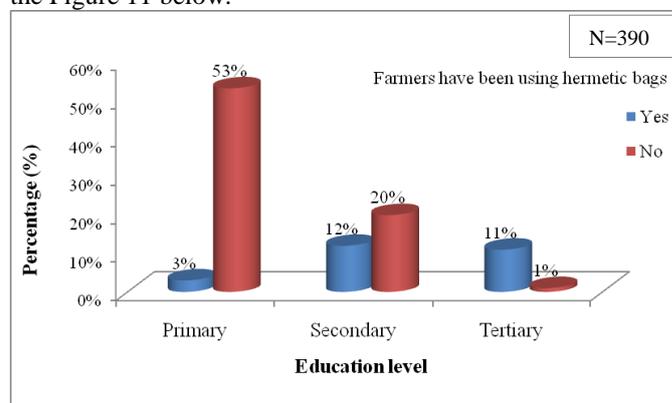


Figure 4.11: Education level of the farmers in Busia County Kenya

The results show that 56% (218) attained only primary education, 32% (125) have attained secondary education, while 12% (47) tertiary education. Cross tabulation was done and it showed that usage of hermetic bags along education levels varied. As shown in the Figure 4.11 above, the trend in the usage of hermetic bag storage technology increases with increase in education level. There was low usage 3% (12) of

hermetic bags among farmers who had only attained primary education. The trend increased to 12% (47) among those farmers who had attained secondary education, and for the 12% farmers with tertiary education, 11% of them used hermetic bags storage technology. Pearson Chi-Square value ( $\chi^2_{4,0.01} = 11.678a$ ) showed that there was highly significant ( $P < 0.01$ ) association between the level of education and the usage of hermetic bags storage technology. The results generally imply that increase in the level of education leads to increased adoption of hermetic bags storage technology.

In agreement with these findings, education levels were highly correlated with adoption rates in agriculture as found by Weir and Knight (2003), and the benefits to the farmer that come from having more education increase with the pace of agricultural technology change (Foster and Rosenzweig 1996). Many technologies are management incentives that draw on a farmer's allocative abilities. Huffman (2000) related farmer schooling to decision making and adoption of technology. Wozniak (1993) demonstrated that managers with more education are more likely to adopt new inputs and contact the extension service for adoption information than were operators with less education. Integrated pest management (IPM), for example, involves designing context-specific pest treatment as opposed to following a prescribed regimen of chemical pesticide application. Weibers (1992) shows that highly skilled farmers were more likely to adopt IPM, and, even after they seek the advice of consultants, educated farmers are likely to spray less pesticide and use the system more effectively.

#### D. ECONOMIC FACTORS LIMITING ADOPTION OF HERMETIC BAGS BY SMALLHOLDER CEREAL FARMERS

There are several economic factors which hinder adoption of hermetic bags. The study sought to identify these economic factors. The results are discussed in the following section.

##### a. COST OF HERMETIC BAGS

The comfortability of using hermetic bags depends heavily on their availability and the economic level of farmers. The researcher wanted to establish how the cost of hermetic bags affected its adoption. The researcher first sought to know why these farmers had not adopted the new storage technology that would reduce their cereal losses. The results were analysed and presented in the Figure 4.13 below.

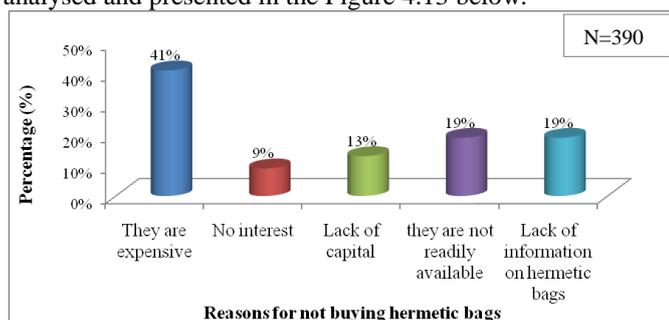


Figure 4.12: Reasons farmers gave for not buying hermetic bags in Butula Sub-County, Busia County, Kenya

The results show that 41% (160) respondents indicated that the hermetic bags are expensive and 19% (74) did not have any information about hermetic bags while 19% (74) said that the hermetic bags are not readily available in the market. Pearson Chi-Square test of independence of value ( $\chi^2_{4,0.01} = 16.185a$ ) showed that there was highly significant ( $P < 0.01$ ) variation in the factors that led to the low adoption of hermetic bags. This meant that adoption of these bags largely depended upon various economic factors as show in the Figure 4.13 above.

These findings do not agree with Murdock *et.al*, (2014) who said that hermetic bags are fairly affordable, costing KSh 250 (US\$ 3) for a bag with a 100 kg capacity. This cost is still very expensive to farmers considering the fact that a normal sisal bag goes at Ksh.35 according to the farmers. There are two brands being marketed in Africa by different companies. Purdue Improved Crop Storage (PICS bags<sup>TM</sup>) and SuperGrainBag<sup>TM</sup>. PICS bag is a simple, low-cost triple bagging technology originally developed for postharvest storage of cowpea but had been evaluated for applicability to maize storage mainly in West Africa. The three layers include an outer polypropylene bag and two inner linings of high density polyethylene (HDPE). Purdue University introduced its PICS bag to the Kenyan market in partnership with local distributor Bell Industry Ltd. Purdue sold over 46,699 PICS bags in Kenya, providing thousands of smallholder farmers across the country access to technology to reduce their postharvest losses by as much as 40 percent (Feed the future, 2014).

##### b. CREDIT SOURCES

In trying to find out how economic factors hinder the adoption of hermetic bags storage technology. The researcher sought to find out if farmers could access credit that could be used in purchasing hermetic bags. The results were analysed and presented in the Figure 4.14 below.

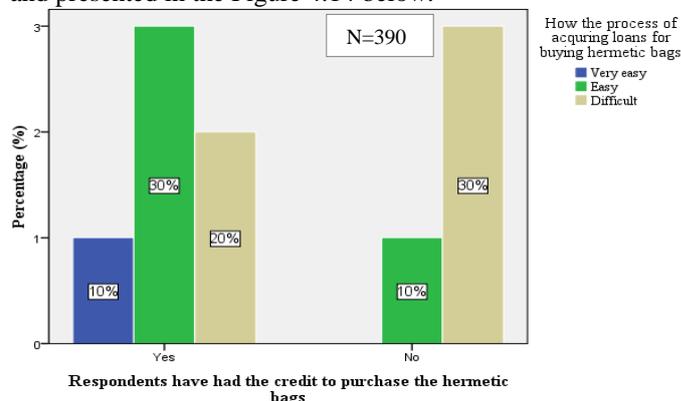


Figure 4.13: Accessibility of credit by farmers to purchase hermetic bags in Butula Sub-county Busia Kenya

The results indicate that 60% (234) respondents who use hermetic bags had been able to access credit while 40% (156) had not been able. However, 50% (195) indicated that it was not easy to access credit

However some farmers had their reasons for not borrowing credit from lending institutions. The researcher analyzed the reasons as presented in the Figure 4.15 below.

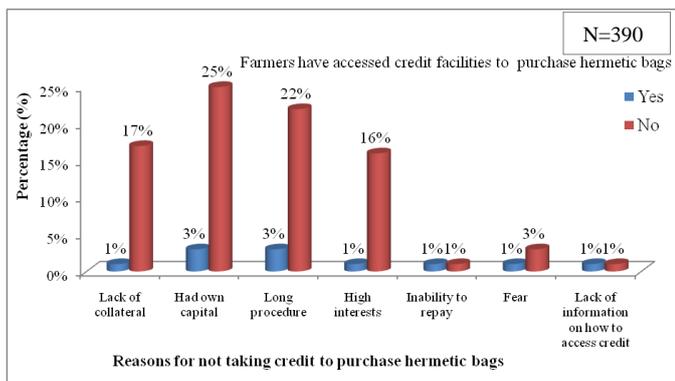


Figure 4.14: Reasons why farmers fail to take credit to purchase hermetic bags in Butula Sub-County, Busia Kenya

The results indicate that 25% (98), did not take loans because they had their own capital, 22% (86) said taking a loan had long procedures, 17% (66) lacked collateral, 16% (62) feared taking loans because of high interests. The conducted Pearson Chi-Square value ( $\chi^2_{2,0.01} = 1.875a$ ) showed that there was highly significant ( $P < 0.01$ ) association between access to credit and the reason for not taking credit to purchase hermetic bags for storage technology. This association implies that lack of access to credit services is the reason why many farmers have not been able to purchase hermetic bags storage technology.

Much has been written on the determinants of technology adoption in agriculture, Christiansen *et al.* (2011) put emphasis on issues such as input availability, knowledge and education, risk preferences, profitability, and credit constraints receiving much attention. In the case of smallholder farmers, limited access to credit may provide an important constraint to technology adoption as lenders may be unwilling to bear the high transaction costs of small disbursements (Poulton *et al.* 2006).

c. DISTANCE TO MARKET

The researcher wanted to know how far farmers travelled to buy hermetic bags. This was to find out about the availability of hermetic bags to the farmers. The results were analysed and presented in the Figure 4.16 below.

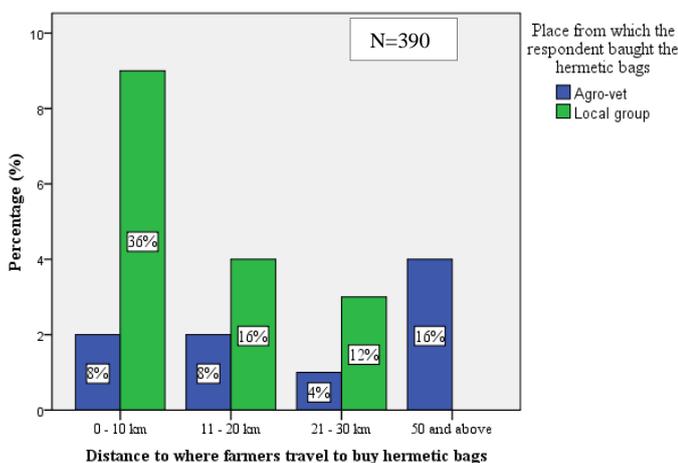


Figure 4.15: Distance farmers go to purchase hermetic bags in Busia county Kenya

The results show that 36% (140) bought hermetic bags from agro vets, while 64% (250) bought from local groups. It was also shown that the farmers who purchased in the agro vets travelled as far as more than 50 kilometers. This showed hermetic bags are not readily available to the farmers, thus low adoption of new storage technology.

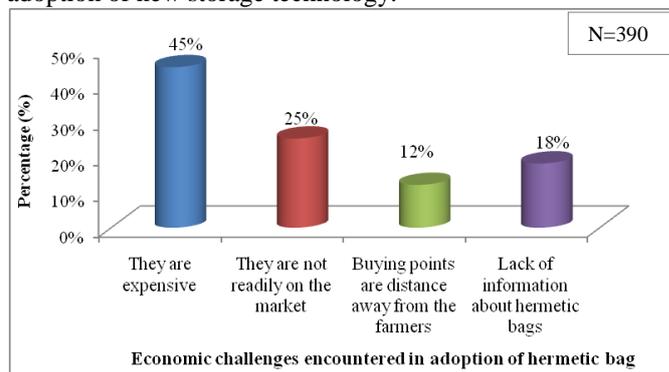


Figure 4.16: Economic challenges encountered in adoption of hermetic bags in Butula Sub-County, Busia Kenya

The results show that 45% (176) farmers responded that the hermetic bags were expensive, 25% (98) said that the bags were not readily available in the market while 12% (47) said that the buying points are a distant away from the farmer. These are some of the economic factors brought out by farmers, which limit the adoption of the hermetic bags in Butula Sub-County of Busia County, Kenya.

In line with the findings De Groote *et al.*, (2013) reported that the bags are commercially available in Kenya and though the market is not fully developed since the technology is still new and the awareness levels are still low.

d. FARM SIZE

Economic factors limiting the adoption of hermetic bags range from market distance from the farmer, the cost of hermetic bags and access to credit services, as discussed in the foregoing sections. This section will discuss how farmers look at land size as one of the economic factors leading to limited adoption of hermetic bags storage technology. The Figure 4.18 below shows the results of land size.

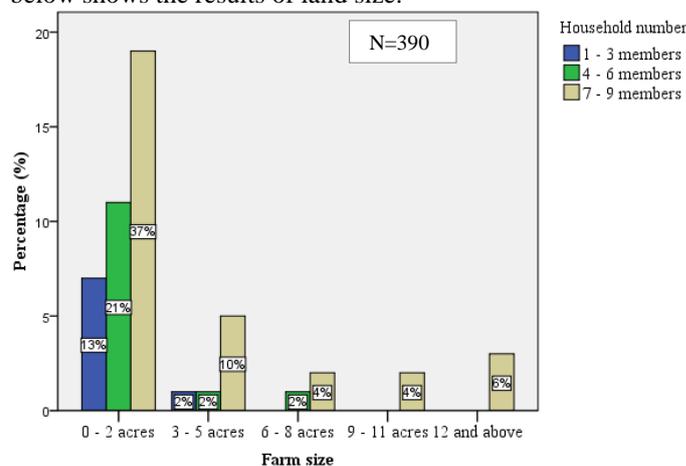


Figure 4.17: Size of farm as an economic challenge to adoption of hermetic bags in Butula Sub-County Busia Kenya

The results indicate that 55% (214) of the farmers have land not exceeding 2 acres, while only 3% (12) have land that is above 12 acres. The results also reveal that 37% (144) of the farmers with land less than 2 acres have 7 to 9 household members. Pearson Chi-Square value ( $\chi^2_{8,0.01} = 5.503a$ ) showed that there was no significant ( $P > 0.01$ ) association between the number of household members and the size of land owned. This means that having a larger household members, does not mean one will have less land for farming. However, the results reveal that most households that have more members have less land for food production. This means that what is harvested cannot even be stored for a longer duration.

Idrisa *et al.*, (2012) confirmed with these findings when he reported that a number of studies, conducted in various parts of Nigeria suggest some factors (constraints) that are responsible for low level of agricultural technology adoption. Some of the major constraints identified are credit facilities, education, extension services, farm size, land tenure system and labour availability.

## V. SUMMARY, CONCLUSION AND RECOMMENDATION

This chapter contains the summary, conclusion and recommendation of the study that was undertaken in Butula sub-county, Busia County.

### A. SUMMARY OF FINDINGS

The study sought to establish factors affecting adoption of hermetic bags among smallholder farmers in Busia County, Kenya. The results indicated that the usage of hermetic bags has not been fully adopted by farmers. It was found that 47% of farmers use hermetic bags for storage. The results showed that 24% of the respondents had bought hermetic bags. The major causes of losses were weevils and rodents. Social factors like education level, age of farmers and the level of awareness caused a limitation to adoption of the new technology. Many smallholder farmers were elderly and less educated and therefore this was a constraint to adoption of new technology. Low adoption was also attributed to economic factors such as small land sizes, long distance to the markets, poor access to credit facilities and the high cost of hermetic bags.

### B. CONCLUSION

- ✓ Hermetic bags use in Butula Sub-county in Busia County was found to be low at 47%. 24% of small holder farmers using the hermetic bag technology purchased them while the rest (23%) received them free from technology promoters. Major cause of losses during post-harvest were found to be weevils and rodents.
- ✓ Majority of small holder farmers do not store grains for a longer period, 95% of them store grains for less than 6 months, and this was because of low productivity and size of land holding.

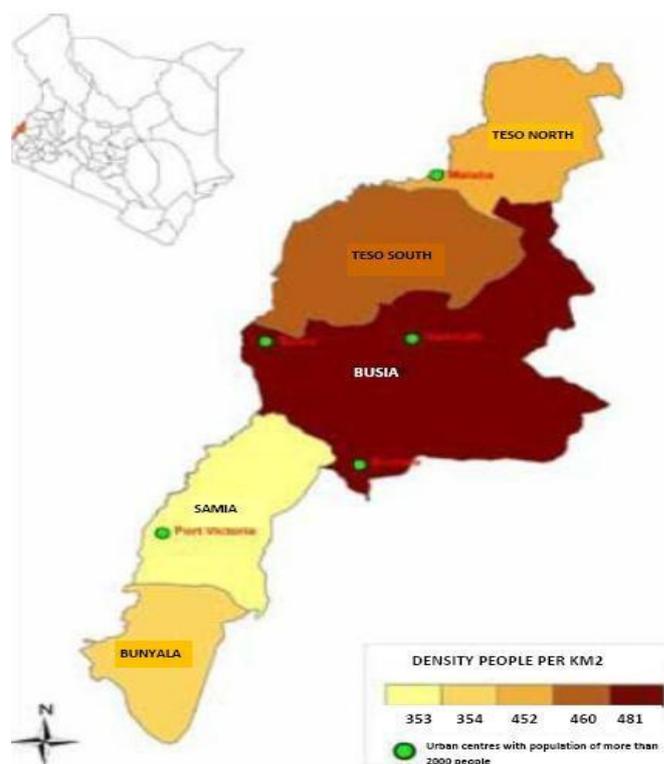
- ✓ Small holder farmer in busia county had Other means of storage which included; traditional granary, sisal and nylon bags
- ✓ Several social factors limited the adoption of hermetic bags. awareness, education level, lack of credit Lack of information on hermetic bags storage technology has played a key role in limiting adoption of the new storage technology.

### C. RECOMMENDATIONS

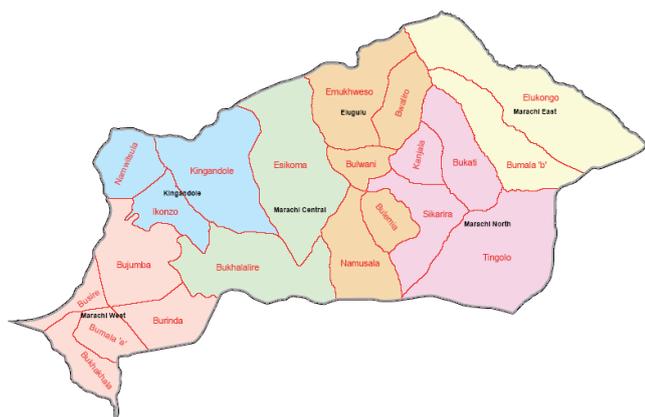
- ✓ The study therefore recommends strengthening of contact between farmers and technology promoters. There is need to improve methods of disseminating agricultural technologies to the farmers through increased demonstrations and trainings, to minimise lack of information about hermetic bags, lack of training, low education levels and extension contacts.
- ✓ The study recommends that prices subsidy by county governments to encourage farmers to adopt the technology.
- ✓ Promoters of the technology should establish distribution networks to ensure availability of hermetic bags within farming community.
- ✓ Recommend use of hermetic bags technology by cooperative groups, private grains stores and national stores(NCPB)

## APPENDICES

### Appendix I: Busia County Map



Appendix II: Map For Butula Sub-County, Busia County



POPULATION 121,870

AREA (Sq.Km) 247.1

Ward Elugulu, Marachi Central, Marachi West, Marachi East, Kingandole, Marachi North.

REFERENCES

[1] A.F, O. (n.d.). Factors Influencing Adoption Decisions Of Maize Farmers In Nigeria. *International Journal of Food and Agricultural Economics*, 2 (3), 45-54.

[2] Adams, M. (1982). *Agricultural extension in Developing countries*. London: Longman scientific and technical.

[3] Adesina, A. A. (1993). Technology characteristics, farmers' perceptions and adoption decisions: ATobit model application in Sierra Leone. *Agricultural economics*,.

[4] Adesina, A. A.-F. (1995). Farmers' perceptions and adoption of new agricultural technology: *Agricultural economics*,.

[5] Africa, A. f. (2014). Establishing the status of postharvest losses and storage for major staple crops in eleven African countries (Phase II). AGRA. Nairobi: Kenya.

[6] Agriculture, M. o. (2013). *Food Security Assessment Report*,. MOA, Department of Crops Management.

[7] Ahmed, A. (2004). Challenges of agricultural technology transfer and productivity increase in the Sudan. *Int. J. Technology, Policy and Management*, 4(2), 136–150.

[8] Ardhendu. (2014). Hermetic Storage: A Novel Approach for Small Scale Farmers. *Discovery Agriculture*, 2014, 2(5),.

[9] Ayinde, O. E. (2010). Determinants of Adoption of Downy Mildew Resistant Maize by Small-Scale Farmers in Kwara State, Nigeria. *Global Journal of Science Frontier Research*, 10.

[10] Baributsa, D. (2011). Personal communication 27 Feb 2011.

[11] Bett, C. N. (2007). Post-harvest Storage Practices and Techniques used by Farmers in Semi-arid Eastern and Central Kenya. *African Crop Science Proceedings* 8,.

[12] Bruin, T. D. (2012). worldwide use of hermetic storage for the preservation of agricultural products. 9th international controlled atmosphere & fumigation conference (CAF), turkey, October 15-19, 2012. World

Bank Policy Research Working Paper. World Bank Policy Research Working Paper No. 4347. Antalya.

[13] Carletto, C. A. (2007). Non-traditional exports, traditional constraints: The adoption and diffusion of cash crops among smallholders in Guatemala.

[14] Christiaesen. (2011). Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. *Journal of development economics* volume 96, issue 2, November 2011, 159–173.

[15] FAO, F. a. (2012). *Monitoring Agriculture and Policies in Africa*.

[16] Foster, A. D. (1996). *Technical change and human-capital returns and investments: evidence from the green revolution* (86 ed.).

[17] Frankel, J. a. (2002). *How to design and evaluate research*. Tokyo Mcgraw Hill.

[18] G.A, M. M. (2003). *Research methods, Quantitative and Qualitative Approaches*. Acts. Nairobi, Kenya.

[19] Hodges, R. B. (2011). Postharvest Losses and Waste in Developed and Less Developed Countries: Opportunities to Improve Resource Use. *Journal of Agricultural Science*.149.

[20] Huffman, W. (2000). Human capital, education, and agriculture. *Staff paper series No. 338*.

[21] IMF. (2011). *Regional Economic Outlook: Sub-Saharan Africa -Sustaining the Expansion*,. Washington D.C.: International Monetary Fund.

[22] J., O. (2006). *Determinants of Agricultural productivity in Kenya*. Egerton University, Tegemeo Institute of Agriculture policy and development.

[23] Kangethe, E. (2011). *Situation Analysis: Improving food Safety in the Maize Value Chain in Kenya*. Kenya National Bureau of Statistics (2009). *Population and housing Census in Kenya*.

[24] Kijima, Y. K. (2011). An inquiry into constraints on a green revolution in Sub-Saharan Africa: The case of NERICA rice in Uganda". *World Development*,, 39.

[25] Kimenju, S. H. (2010). *Economic Analysis of Alternative Maize Storage Technologies in Kenya*. . Contributed Paper Presented at 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September, 19-23.

[26] Komen, J. M. (2006). *Economics of Post Harvest Maize Grain Losses in TransNzoia and Uasin Gishu Districts of NorthWest Kenya*. Kitale: Kenya Agricultural Institute.

[27] Marenja, P. P. (2009). Soil quality and fertilizer use rates among smallholder farmers in Western Kenya". *Agricultural Economics*, (Vol. 40).

[28] Misoke, H. K. (2010.). Personal communication 9 Oct.

[29] Moussa. (2009). Evaluating the Effectiveness of Alternative Extension Methods: Triple-Bag Storage of Cowpeas by Small-Scale Farmers in West Africa. Selected paper prepared for presentation at the Agricultural & Applied Economics Association, 2009 AAE. AAEA & ACCI Joint Annual Meeting, Milwaukee, Wisconsin, July 26-29, 2009.

[30] Mumbi, R. &. (2011). *Zambia: Climate Information Alerts Boost Poor Farmers*.

[31] Nassiuma, D. (2000). *Survey Sampling: Theory and Methods*. Nairobi: Nairobi University Press.

- [32] National Council for Population and Development: Ministry of State for Planning, N. D. (2012). Sessional Paper No. 3 of 2012 on Population Policy for National Development.
- [33] Network, P. (2011). Postharvest loss.
- [34] Ochola, W. B. (2014). Attitudes among Extension Agents, Researchers and Farmers and their Effects on Adoption Rates of Agricultural Technologies. *Journal of Science Technology Education and Management*, Vol. 6 Nos.(1& 2.), 69-82.
- [35] Oster, E. a. (2009). Determinants of technology adoption: Private value and peer effects in menstrual cup take-up mimeo. University of Chicago.
- [36] P.J. Anankware, A. F.-O. (2012). *Academic Journal of Entomology*, 5(1), 47-53, 2012.
- [37] Pingali, P. K. (2005). *Commercializing Small Farms: Reducing Transaction Costs*, Rome, Food and Agriculture Organization of the United Nations.
- [38] Plan, F. M. (2008-2012). *Kenya Vision 2030*.
- [39] R.C, K. (2013). Determinants of agricultural information access by small holder tea farmers in Bureti District, Kenya.
- [40] Rembold, F. H. (2011). *The African Postharvest Losses Information System (APHLIS)*. EUR 24712.
- [41] Republic of Kenya. (2010). *Agricultural Sector Development Strategy 2010–2020*. Nairobi: Government Printer.
- [42] Republic of Kenya. (2010: ). *Kenyan Constitution, 2010*. Nairobi: Government printer.
- [43] Schultz, T. (1975). The value of the ability to deal with disequilibria. *Journal of Political Economy*, 13:827–846.
- [44] T.S, M. M. (2006). *Agricultural extension in Kenya: practice and policy lessons*.
- [45] Tefera, T. K. (2011). The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries .
- [46] Weibers, U. (1992). *Economic and environmental effects of pest management information and pesticides: The case of processing tomatoes in California*, Ph.D. Dissertation. University of Berlin., Department of Agricultural Sciences, Berlin.
- [47] Weir, S. J. (2003). The role of education in facilitating risktaking and innovation in agriculture. *Journal of Development Studies* 39(6), 1-22.
- [48] Wozniak, G. (1993). Joint information acquisition and new technology adoption: Late versus early adoption. *The Review of Economics and Statistics*.
- [49] Zorya S., M. N. (2011). *Missing Food: The Case of Post harvest Grain Losses in Sub-Saharan Africa*. Report Number 60371-AFR (April 2011). Washington D.C: WorldBank.