UNIVERSITY FOR DEVELOPMENT STUDIES

PRACTICES AND CONSTRAINTS OF FARMERS IN THE STORAGE AND PEST MANAGEMENT OF SORGHUM AND MAIZE IN THE SAVELUGU-NANTON DISTRICT OF GHANA

ABDULAI MURPHY MAHAMADU

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ABDULAI MURPHY MAHAMADU (BSc APPLIED BIOLOGY)

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CHANGE

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DECLARATIONS

STUDENT DECLARATION

I hereby declare that this research is the result of my own work and that, to the best of my knowledge; it contains no material previously published by another person, except where acknowledgement has been made in the text.

Name of Student

Abdulai Murphy Mahamadu	Signature	Date
	....	....

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this dissertation was supervised in accordance with the guidelines on supervision of dissertation laid down by the University for Development Studies

Name of Supervisor ....

Dr Abu Moomin	Signature	Date

ABSTRACT

This study examines the practices and constraints of farmers in the storage and insect pest management in the Savelugu-Nanton District of Ghana. Data were collected from 187 farmers with the aid of structured and validated questionnaire. Respondents were selected using a two stage simple random sampling technique. Data was analysed using descriptive statistics and ordered probit regression model. The results showed that the following storage facilities were available and used by farmers in the study area: mud rhombu (57.8%), Kambog (15.5%), the woven basket (16.0%), pots (5.3%), bag (13.3%), and open platform (5.3). Respondents indicated that their storage facilities have not been very efficient. It thus, predisposes the grains to serious attacks from biotic constraints such as insects, birds, rats and moulds. Respondents reported that for every bag of grain stored about a bowl is lost to insect pests infestation. The main insects that affect the grains were reported to include grain weevils, grain borers, grain beetles and grain moths. The control measures adopted by respondents were mentioned to include physical, chemical and phytochemical measures with emphasis on the use of traditional botanical pesticides. From the ordered probit results, six variables, namely, age, sun drying, storage walls, roofs, floors, and general condition of storage structure were found to have significant effect on storage practices of farmers. From the findings of this study, it was recommended that the government should provide farmers with modern storage facilities educate farmers on adequate storage methods such as harvesting at the right time, drying grain to safe moisture content before storage and disinfect grains of insect pest before storage. If these recommendations are implemented, the storage problems and the resultant food insecurity will be ameliorated.

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DEDICATION

This work is dedicated to my family.

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LIST OF ACRONYMS

AGST ....Agricultural and Food Engineering Technology Service

AMCOST............................ African Ministerial Council on Science and Technology

CIRAD .... (French Agricultural Research Centre for International Development)

FAO...................................Food and Agriculture Organisation

FAOSTAT ....Food and Agriculture Organisation Statistics

GDHS................................Ghana Demographic and Health Survey

GLSS ....Ghana Living Standard Survey

GSS....................................Ghana Statistical Service

IAEA ....International Atomic Energy Agency

IITA .... International Institute of Tropical Agriculture

PHC ....Population and Housing Census

USDA ....United State Department of Agriculture

UNDP ....United Nations Development Programme

WFP...................................World Food Programme

WPP...................................World Population Prospects

CHAPTER ONE

INTRODUCTION

1.1 Background

The role of food storage in the attainment of food security cannot be underestimated. Annually cereals and grains, the most important staple food for about 1.2 billion people (IITA, 2009) and occupies a third of the cultivated area globally (Blackie, 1990), are lost to pests and spoilage due to either poor storage or perishability. According to the Food and Agricultural Organisation, (FAO, 2015) up to one third of food is lost before it is consumed by people and this is especially in at a time where almost a billion people go hungry globally.

In Sub Saharan Africa, about 30 million tons of grain and oilseed are lost each year in the production, handling and processing stages of the food supply chain, and before it gets to storage. Poor storage practices exacerbate spoilage that begins on the field due to poor cultural practices and handling.

About 1.2 million people, representing 5 percent of Ghana's population, are food insecure. Thirty-four percent (34%) of these are in Upper West region, followed by Upper East with fifteen percent (15%) and Northern region with ten percent 10% (approximately 453,000 people) (WFP, 2009). About forty percent (40%) of people in the rural areas of Northern Ghana are vulnerable of becoming food insecure if nothing is done about the situation. The peculiarity of the northern region of Ghana, which has the potential of becoming the food basket but where food production depends on rain fed agriculture with only one season of uncertain rainfall, makes the food security discussion more relevant. Reducing food loss thus becomes important because it makes more food available for consumption and this is crucial in low income and food deficient societies such as northern Ghana.

The main effort towards increased food production has been directed towards greater agricultural production through efficient cultivation, but farmers who cultivated crops at various points of the rural agricultural landscape are known to have encountered heavy financial and food losses due to poorly constructed storage facilities and practices, and this exposes grains to insect pest attack in storage country with the resultant food insecurity. Therefore the importance of good storage facilities and practices to food security cannot be overemphasized (Ebewore *et al.*, 2013). The need for good storage practices and facilities for harvested produce, which has been made possible with such cost and difficulty, has not received sufficient recognition. The main problem has been due to lack of understanding of the magnitude of losses that occur during harvesting and in storage. Similarly, there is no agreed definition of grain "loss" or grain "damage". This is due to the fact that the storage losses are of a multiple nature, including losses in weight, quality, nutritive value, and market value. Grain loss is the measurable decrease of food grain, which may be qualitative or quantitative. While grain damage is defined as the superficial evidence of deterioration, for example, holed or broken grains, from which loss may result. Each of these types of losses may have different significance that varies with people. To ensure constant food supply it is thus important to maintain the quality and value along the entire production and supply chain to ensure that consumers have access to food that is safe, nutritious and healthy.

Food availability and accessibility can be increased by increasing production, improving distribution, and reducing the losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security. When the reduction is achieved, it would increase the amount of food available for human consumption and other industrial uses, and increase real income for farmers and consumers and improve food security (Mundial, 2008; Trostle, 2010, World Bank, 2011).

This study focuses on the potential that storage practices and facilities play in reducing food losses to pest as a key to improving food security. Its emphasis is on insect pests and food storage practices, storage facilities and insect pest. This is against the knowledge that, it is not likely that there is any one simple solution and that multiple approaches will be needed in dealing with the problem including the use pesticides.

1.2 Problem statement

Over seventy percent (70%) of Africans derive their livelihood from agriculture, which is also the most important enterprise and key to economic development of the continent (FAO, 2015). Unfortunately, significant amounts of particularly, the cereal crops that are produced are lost through storage insect pests' thus aggravating food insecurity (Pantenius, 1987 and Ngamo & Hance, 2007). Insect pests account for grain losses of up to 20% - 30% worldwide (Lenne, 2000) and these loses include weight, nutritional and economic losses (Magrath *et al.*, 1996; Boxall, 2002). Insect pests of stored cereals are cosmopolitan and polyphagus in their feeding behaviour which makes controlling them difficult particularly when the conditions are conducive for them to thrive in storage and food produce is lost (Ofuye and Lale, 2001). These losses could be influenced by poor cultural practices on the field, poor harvesting and storage practices, the storage time and the population of insects involved in the infestation (Tefera *et al.*, 2011).

Statistics indicate that about 925 million people worldwide do not have enough food to eat, and with the growing world population that is estimated to hit 9.1 billion by 2050 (Cohen 2003; WPP, 2008 & IAEA, 2011), it is imperative that these losses are minimized. Almost thirty-three percent (33%) of the African population are malnourished and tropical African countries are among the worst in attaining food insecurity (Pantenius, 1987; Ngamo & Hance, 2007).

In Ghana over sixty percent (60%) of the population depends on Agriculture for their livelihood (Al-Hassan & Diao, 2007), particularly the Northern Ghana where majority of the population is into Agriculture. With a population of close to 21 million, more than thirty percent (30%) of Ghanaians live below the poverty line (UNDP, 2005) and per capita income is a little over $600. About fourteen percent (13%) of the population (About 2.5 million people) had dietary composition below minimum level in 2002 while prevalence of child malnutrition was about 22% in 2003; thirty percent (30%) stunted, seven percent (7%) underweight and twenty-two percent (22%) wasted (GDHS, 2003). The northern parts of Ghana comprising of Northern, Upper East and Upper West Regions have been described as the most poverty stricken and hunger spots in Ghana (GLSS, 2000). Chronic hunger is a problem that is inextricably linked with poverty, one resulting in the other especially because of the negative effect it has on children by stunting their growth and development (Conway & Waage 2010).

The Savelugu-Nanton district face considerable postharvest loss due to storage problems as a result of infestation by insect pests, decay and physical injuries caused by handling, packaging and transporting (Acedo & Weinberger 2006). Poor and inadequate storage facilities have been identified with food shortage, loss of income by farmers, scarcity of food and food wastage during harvest period, leading to food insecurity. Farmers who could not afford to get their products to the market due to poor transport and storage facilities are forced to sell them at very low prices to middlemen, who eventually made more money than the farmers (Ewuim *et al.*, 1998). Food scarcity is usually higher during the wet season especially before the first harvest in June, this means that farmers and their families are under nourished just at the period when the work load for weeding and other maintenance practices are high (Upton, 1997).

Much research has been done into the subject in Ghana and Northern Ghana as an entity, but little or no research has been conducted into the subject of how storage practices have impacted food security in the Savelugu-Nanton district. It is for this reason, that this research is being conducted.

1.3 Justification

Obtaining enough food is an important concern for every nation in the world, and in some countries food shortage is an extremely serious problem. The on-going effects of the food crisis are caused in part by very high losses of grain during storage, which in turn has resulted in the starvation of 925 million people worldwide (FAO, 2006). Reduction in the losses will enhance food security which is a growing concern and enough food available for human consumption, feeding of livestock, provide raw material for industrial purposes (Adedire & Ajayi, 1996).

Storage facilities are to be used for preservation of food and other agricultural produce for future use in order to meet these essential needs in the period of emergencies such as famine, poor harvest season and drought. Studies highlight three techniques of storage involving different structures in Africa (Adesuyi et al., 1980; Udoh et al., 2000), namely: traditional/local grain storage; improved/semi modern grain storage techniques; and modern centralized storage. Farmers usually make use of storage techniques that are most suitable to them and their pocket at a point in time (Asiedu et al., 2002).

Government policies, both past and present, tend to address the issue of food security without taking practical measures for providing adequate storage facilities. The findings of this study would serve (i) as a tool for directing future research and agricultural planning in the district, (ii) as a basis to calculate justifiable expenditure on storage and control, (iii) in estimating damage that justifies control, and in estimating the effectiveness of control measures.

1.4 Objectives

1.4.1 Main objective

The main objective of the study is to assess the practices and constraints of farmers in the storage and insect pest management of sorghum and maize in the Savelugu-Nanton district of Ghana

1.4.2 Specific objectives: Specifically, the study seeks;

- To determine the socio-economic characteristics of respondents
- To identify the various storage facilities available and used by farmers.
- To evaluate the conditions of these storage structures in storing grains
- To determine the problems associated with grain storage
- To determine the relationship between storage practices of the farmers and their socio-economic characteristics and,
- To make appropriate recommendations based on the findings.

1.5 Research questions

The study will be guide by the following research questions:

- What are the various storage facilities available to and used by farmers in Savelugu-Nanton district in storing their agricultural products?
- Are these facilities effective in storing agricultural products in the area?
- What are the pest problems encountered by farmers in storing their products?
- Can anything be done to improve storage facilities?
- Is there any relationship between farmer's storage practices and their socio economic characteristics?

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter presents a literature review on the subject of investigation. It highlights the economic importance of maize and sorghum, storage methods of sorghum and maize, the influence of biotic and abiotic factors of grain storage, the effect of storage structure architecture, the maize weevil, length of storage of maize and sorghum, and control measures.

2.2 Economic importance of maize and sorghum

Maize and sorghum crops are grown in more countries than any other cereal in the world (Morris, 2001; and FAO, 2007). Africa produces seven percent (7%) of the world's maize with South Africa and Egypt being the main producers (FAO, 2007). In sub-Sahara Africa, excluding South Africa, the bulk of maize produced is by small holder farmers in individual or in groups (Odogola & Henriksson, 1991; and Lyon., 2000).

The important cereals produced in Ghana are maize, rice, sorghum and millet. At the national level, cereals and cereal products come only second to tubers, and account for about fourteen percent (14.4%) of total consumption of home produced food. In terms of cash expenditures, cereals and cereal products account for fifteen percent of household food consumption (ISSER 2002). In the latest living standards measurement survey, of the estimated total number of households who harvested staple and or cash crops within the twelve month period preceding the survey, majority (2.5 million) harvested maize. Other major crops, in terms of number of households involved, are sorghum/millet/guinea corn (848,527). Estimates of the number of households in each ecological zone that harvested different crops during the reference period shows great variation in types of crops grown around the country. Maize is the only staple grain which is grown extensively in all of coastal, forest and savannah zones (GGDP, 1991; and Onumah & Coulter, 2000).

In Ghana, farm holdings are small, ranging between 1 and 2 ha with only fifteen percent of maize farmers in the major producing areas cultivating more than 2 hectares (Onumah *et al.*, 2000). Maize and sorghum are an important source of carbohydrate, oils, vitamin B and minerals (IITA, 2007). Almost every part of the maize and sorghum plant is utilized (Romain, 2001). The bulk of maize and sorghum produced is used as livestock feed and as a raw material for industrial processing. In Ghana it is mainly used for human consumption (Aquino *et al.*, 2001). Of the total maize and sorghum produced in Ghana between the period 1995 to 1997, Seventy-five percent (75%) and six percent (6%) were used for human and livestock consumption respectively (Aquino *et al.*, 2001). These versatile crops are also major sources of income and employment for many. Sorghum especially can be processed to further improve its feed value and techniques such as grinding, crushing, steaming, steam flakes, popping and extruding have all been used to enhance the grain for feeding. The products are then fed to beef and dairy cattle, laying hens, poultry and pigs. Sorghum is also an alternative grain that is used in cooking for people who have celiac disease and cannot tolerate gluten (protein in wheat, rye, and barley) (Fasano *et al.*, 2003).

Sorghum has the highest carbohydrate level of seventy-seven percent (77.2%), total dietary fiber five percent (5.2%), protein about eight percent (7.7%), total lipid about four percent (3.5%) and fatty Acids (USDA, 2009). The milled grains are used in preparing food (tuo zaafi, koko and masa) and the local opaque beer known as pito. Sorghum brewing is an important cottage industry in northern Ghana. The leaves of sorghum serve as fodder for farm animals while the stalks are used for fencing, staking, roofing, weaving baskets and mats and also for fuel. Beyond food security and provision of cash the value of sorghum is linked to the social, economic, religious, nutritional, and health aspects of farmers' lives. Sorghum is mainly cultivated and consumed by the lower strata of society. The three Northern regions where it is widely grown are among the poorest. More than forty percent of the population in these regions lives below the poverty line (Ghana Statistical Service, 2000).

Products resulting from industrial processing of maize include starch, high fructose syrup, dextrose, corn oil, ethanol, cosmetic or skin care products, beverages, crayons, soaps, absorbent material for diapers, food additives, biodegradable plastics and food supplements. Other products are livestock feed and other components such as fuel (Halm *et al.*, 1996; Cardona *et al.*, 2007; and Yong, 2003). Corn starch is used mainly as a thickener or as a stabilizer of other ingredients such as baking powder, candies, puddings and other prepared food mixes. Paper and textile industries also utilize corn starch. Corn oil is used for making salad, as cooking oil and in the production of margarine. It is also used as a carrier for some vitamins and medicines (Dupoint *et al.,* 1990). On the other hand dextrose is utilized in the bakery industries where it serves as a yeast nutrient, and provides some sweetness and browning of the crust on baked products. Other major uses of dextrose are in food canning, frozen packaged foods, ketchup, jams and jellies, soft drinks, wines and malt liquors (Okoruwa & Ling, 1996). Maize can also be used to produce bio-ethanol and used as a gasoline additive, which when used as fuel can help reduce air pollution (Yong, 2003).

2.3 Storage methods of maize and sorghum

The quantity of grain produced in a season influences the nature of storage method and the duration of the storage period (Owusu, 1981). At a small farming scale, grains are stored traditionally in different types of containers, depending on the farmer's socio-economic status and his environment (Audette & Grolleaud, 1983). Structures used at the local level are often inexpensive and environmentally motivated. Subsistence stores may be made out of clay, thatch, mud, wood or stones (Rukuni *et al.*, 1988; and Bani, 1991). Larger granaries, meant for storing large quantities for longer periods of time may be built with more permanent structures, as in the case of metal silos or wooden granaries with iron sheet roofs. Open storage is probably the most common system used traditionally in sub-Saharan Africa, especially in the humid areas, where the crop is harvested with high moisture contents and continues to dry in the store. Open structures can simply be wooden platforms on stakes or posts, on top of which the crop rests either in heaps or regular layers. A straw roof is usually provided to protect the crop from rains. Farmers may use fire underneath this structure for insect control and to provide further drying. An even simpler method is hanging the crops in frames or sheaves to tree branches, which is applicable for smaller quantities that would be rapidly consumed. Open storage provides natural ventilation and allows for further drying of the crop. It also discourages development of fungi due to continuous aeration. However, open storage does not provide adequate protection against insect pests or other animals such as birds and rodents (Appert, 1987; and Gwinner *et al.*, 1996).

A more protected storage system, adequate for the semi-arid regions of Africa, is the use of Cribs (FAO, 1985; and Appert, 1987). Cribs are wooden four-cornered structures with ventilated sides. The sides are covered with woven straws, grass stalks or wire netting materials and a thatch roof is provided on top. An elevated floor is made out of wooden branches and attached to the posts about 50 cm above ground. This structure proved to be excellent for drying maize, where it is made out of bamboo and used mainly for drying and storing maize cobs. It is also used in other humid regions of sub-Saharan Africa with considerable success.

In the dryer regions of Africa, where crops can be harvested with satisfactory low moisture contents, more closed types of granaries are used. Different sizes and types of such closed structures are widely spread in Africa, where they can be made out of mud, woven straws or a mixture of mud and chopped straws. Farmers in the semi-arid zones of sub-Saharan Africa, such as Mauritania, Senegal, Mali, Niger and Chad, use a mixture of clay or mud and straw called "Banco" to build concealed granaries. Banco granaries can be four cornered, spherical, with a straw roof containing a protective lid, or in the shape of a cone with the tip pointing downwards and resting on a foundation of stones. Grains inside these banco granaries are well protected against rains and the invasion of insect pests. If the structure is well built and maintained, insect pests would find it very difficult to survive inside due to the lack of oxygen. Granaries made out of mud or clay provides a cool environment that keeps grains viable for germination.

Open Platform (Cameroon)

Woven basket (Cameroon)

Woven Basket (Burkina Faso)

Pots (Cameroon)

Mud Rhombu (Cameroon)

Mud Rhombu (Nigeria)

Plate 1: Some traditional storage structures in Africa

In some parts of Africa, such as Morocco, Mauritania, Nigeria, Chad, Cameroon and Somalia, grains are stored underground (Bartali *et al.*, 1990; Bakhella *et al.*, 1993; and Lemessa & Handreck, 1995). However, it is not as widespread in the African continent as it is in India where an underground pit, between 2 and 2.5 meters in depth, is dug in soil and a fire may be lit to dry up the walls. Afterwards, bricks can be used to build a wall or otherwise walls are plastered with clay and the bottom is covered with chopped straws or husks. The pit is sealed from the top with a roof at or slightly above ground level. Underground storage provides excellent protection to the stored products especially in arid areas, and may also be applicable in rainy areas provided that the entry of both ground and rain water is prohibited through careful cementing and lining of the walls (Mantovani *et al.*, 1986; Smith & Sanders, 1987). Smaller amounts of grains can be stored in different types of containers, calabashes, clay pots, sacks or woven baskets (Kennedy & Devereau, 1994). Such containers allow for frequent consumption of the product on a daily or weekly basis. Baskets can be made out of local plant materials and may themselves be placed inside the granary or in the farmer's house. Jars made out of clay are also used to store beans or cowpeas, as in West Africa, where they are usually placed inside the farmer's house. Jars have a narrow opening and are hermetically sealed with a stone on top. Hermetic storage leads to depletion of oxygen and accumulation of carbon dioxide inside the container, which eventually lead to elimination of insect pests (Mantovani *et al.*, 1986). Traditional storing systems can be satisfactory if built and maintained properly. Recently, farmers in sub-Saharan Africa started adopting newer storing systems. Concrete or metal silos, with capacities up to 5 tons of cereals, are now used in many parts of the continent among medium scale as well as large scale farmers. The use of plastic sacks, bag storage, prefabricated iron halls and flexible plastic silos are increasingly gaining ground among farmers for short-term storage (Peterson & Simila, 1990; Compton *et al.*, 1993; Bartali, 1994). Large warehouses and metal silos, run under state control, are common among cooperatives and traders. Centralised storing has emerged due to the change in the social and economic structures of the farm community. Centralised stores can be large metal constructions that may contain up to three thousand (3000) tons of produce. Though the adoption of bulk storage has led to a significant decrease in the amount of food stored by small scale farmers for emergencies, it does form an important function in sustaining sufficient food supply. Bag storage in large warehouses is a suitable system for bulk storage in the tropics and sub-tropics (Carvalho *et al.*, 1994; and Cabrera & Lansakara, 1995)

Maize storage in Ghana is predominantly in traditional cribs with cobs drying out gradually through natural ventilation. There is also the improved narrow crib which enhances faster drying and storage (Nicole *et al.*, 1997). There are three main traditional storage systems based on type and location and these are; indoor, outdoor and underground systems (Osei-Akrasi, 1999). The indoor and outdoor structures are usually used to store both shelled and unshelled maize but the underground storage is for shelled maize and it is used in drier regions. Thus, maize storage structures tend to be specific to a climatic zone and are constructed to meet the requirements of that particular area (Nicole *et al.*, 1997). Small quantities of seed maize are usually stored indoors using calabashes, gourds and earthenware clay pots at the rural household level. On the large-scale maize is stored in jute sacks or bins in large warehouses after shelling, drying and treating with the recommended storage pesticides. Many farmers store their maize cobs with the husk on, which does not significantly affect the rate of grain drying in cribs (FAO, 2007). Undehusked maize and grains on the cob are less susceptible to weevil attack than the shelled, but shelled maize suffers less damage from other pest such as *Prostephanus truncatus* the larger Grain borer, and (Coleoptera: Bostrychidae) than maize stored on the cob (Hodges & Meikle, 1985).

2.4 Influence of biotic and Abiotic factors of grain storage

All stocks constitute an entity made of the grain to be stored on one hand, and the environment where they evolve on the other hand, and where they are subjected to different attacks causing enormous losses. All of these losses are linked to two principal factors, which may be abiotic (granary architecture, humidity and temperature) or biotic (micro-organisms, rodents, birds and insects) (Scotti, 1978).

2.4.1 Effect of Storage structure architecture on stored produce

The typical African traditional storage structures expose the grain to insect attack and favourable weather conditions increases the proliferation and those of micro-organisms and rodents. One of their major weaknesses is the presence of a single orifice for loading and removing grains, which also serves as an entry port for pests (FAO, 1994; Ngamo, 2000; and Adejumo & Raji, 2007). The structures are generally not hermetically sealed, giving room for pests to make their way into the structures. When constructed of plant materials, rodents easily destroy the structures and favour other sources of infestation (CIRAD, 2002). Many authors have contended that a major cause of losses in traditional granaries is the lack of hygiene (Bell, 1996; Ngamo, 2000; and Hoogland & Holen, 2001). At the time of filling the storage structure with newly harvested grain, the residues of old grain are not always completely removed, and these serve as a source of infestation for new grain, especially if the old grain was infested. Impurities can attract pests from the exterior. Danho *et al.*, (2003) showed that infested grain is attractive to pest insects, particularly to females for oviposition. Farmers in most areas of Eritrea keep old and new harvested grains in the same vicinity, which causes an easy migration or infestation of the new grains from the old grains (Haile, 2006).

Humidity is the principal climatic element which acts in the storage system. Traditional cribs for example give room for limited air circulation, and when grain is not very dry there is an increase in grain moisture content in the structure (CIRAD, 2002). Biological activity occurs only when moisture is present. Therefore, the moisture content of the product itself, as well as the moisture content of the surrounding air, is important for safe storage (Hayma, 2003). Stored products, as well as the organisms attacking stored products are living things: they respire. During respiration oxygen is used up and carbon dioxide, water and heat are produced. The rate of respiration, and thus the amount of carbon dioxide, water and heat that are produced is strongly dependent on the temperature and the moisture content of the product. Higher temperature and moisture content values of grains favours insect and fungus development and a decline in the germination capacity of the grains (Hayma, 2003).

Living organisms like insects, rodents, birds and micro-organisms are serious threats to the traditional storage systems of Africa (Ngamo, 2000; Nukenine *et al.*, 2002; and Haile, 2006). Amongst these living organisms, insects are responsible for the greatest storage losses in cereals and pulses. Traditionally, the grain weevils (*Sitophilus spp*.) and the Angoumois grain moth (*Sitotroga cerealella*) and three genera of bruchids (*Acanthoscelides*, *Zabrotes* and *Callosobruchus*) on pulses are the most important pests of stored grain in Africa (Abate *et al.*, 2000).

Wheat and sorghum in storage were attacked by weevils, (*Sitophilus spp*.), confused flour beetles, *Tribolium confusum* Jacquelin du Val, saw-toothed grain beetles, *Oryzaephilus surinamensis* (L.) and mites (Haile, 2006). The most significant pearl millet pest in Namibia is reported to be *Corcyra cephalonica* Stainton (Lepidoptera: *Pyralidae*) (NRI, 1997). These moth infestations result in masses of grain held together by webbing (silk) produced by the larvae as they move through the grain seeking a pupation site. Many individual grains have their embryos removed by the feeding larvae. In order to use the grain, they have to be rubbed and sieved to remove the webbing, or alternatively the masses of clumped grain are fed to chickens (NRI, 1997).

Mould (1973) reported that there are about twenty (20) different insect pests that attack stored maize in Ghana, of these the maize weevil, *S. zeamais* is the most important primary pest.

However, the larger grain borer, *P. truncatus* has assumed a primary pest status (Vowotor *et al.*, 2005). In a survey conducted in the Ashanti Region to identify the type of storage insect pest associated with maize damage (Owusu (1981) reported only two storage pests and that *S. zeamais* was abundant in all the stores sampled. On the average, fifteen of maize harvested in Ghana is lost annually to *S. zeamais* (Youdeowei and Service, 1986) with localized heavy losses in parts of the country.

2.5 Current post-harvest losses and the risk of insect pest infestation

World Food Supply is the quantity of food, including food stored from previous years, available for people to consume at any given time (FAO, 2009). Obtaining enough food is an important concern for every nation in the world, and in some countries food shortage is an extremely serious problem. The on-going effects of the food crisis are caused in part by very high losses of grain during storage, which in turn has resulted in the starvation of nine hundred and twenty-five (925) million people worldwide (FAO, 2006), including people who suffer from undernourishment. Grain, or cereal, production plays a significant role in the world's food security.

Food and Agriculture Organization of U.N predicts that about 1.3 billion tons of food are globally wasted or lost per year due to insect pests (Hall, 1970, Gustavasson, *et al.* 2011). Thus, losses associated with these crops limit the potential income of the farmers, threaten food security and exacerbate conditions of poverty among rural households, whose income stream depends on the ability to store excess farm produce for a later date (Ntiokwana 1999; Thamaga – Chitja *et al.*, 2004), and reducing food loss can directly increase the real incomes of the producers (World Bank, 2011).

A primary source of insect pest infestation commences in the field but most damage is done during storage (Yuya *et al.*, 2009; Abass *et al.*, 2014). Storing generally leads to a degree of quality change in the product due to seed's respiration, which depletes seed's nutrients over time (Hodges, 1989; Piergiovanni *et al.*, 1993; and Kadlag *et al.*, 1995). The problem can be more complex if the crop is planted or stored near old granaries, which is the case with most of the farmers in the study area. The infestation can easily move to and from storage sites. Moreover, using the same barn year after year without proper sanitation provides favourable atmosphere for a chain of infestation. Store sanitation is essential for the prevention of re-infestation of newly stored grain (Suss *et al.*, 1993; and Rotundo *et al.*, 1995). Insects can hibernate and continue to feed on wooden frame structures of the store or hide between holes and cracks in the walls. They can then re-infest the new crop in the same store and resume feeding. This sort of loss lowers the income and standard of living of the farmers and also leads to waste of a large fraction of the contribution to the nation's food supply (Asiedu and Van Gastel, 2001; FAO, 2004).

Production figures for the past four years have shown significant post-harvest losses from the year 2008 to 2011. A record of fourteen percent loss for maize and twenty percent loss of sorghum by the Savelugu-Nanton District MoFA report for 2011 and this has to be overcome if they are to maximize the benefits from production of durable (cereal) crops.

2.6 Length of storage of maize and sorghum

Grain storage periods generally range between three and twelve months across Africa. The length of storage depends on the agro-ecological zone, ethnic group, the quantity of commodity stored, the storage condition, the crop variety stored, etc. (Hell *et al.*, 2000; Ngamo *et al.*, 2007). The length of storage of grains tends to be longer in the dryer areas of Africa. Ngamo *et al.*, (2007) reported an increase in storage length from three to eight months to over twenty-four months. Maize is usually stored between three and twelve months (Hell *et al.*, 2000). Storage for five to twelve months is common in the Savanna areas. In the Forest/Savanna Mosaic, a few farmers store maize for more than twelve months. In most ethnic groups in the north, the size of maize stores is used to assess the wealth and social prestige of their owners and maize can be stored for up to three years (Smith, 1991). The length of grain storage in Nigeria is between five and twelve months, except for soybean with usually less than five months storage because of its high demand (Ivbijaro, 1989). However, a maximum storage period of between seven and ten years for sorghum and millet was recently reported by Adejumo and Raji (2007). Keyler (1996) reported that the fear of the effect of drought made farmers store grains from four to about seven (6.5) years.

2.7 Biology of the maize weevil (Sitophilus zeamais)

The adult weevils appear on maize in the field as soon it reaches the roasting ear stage. Oviposition, however, does not begin until the ear becomes firm. At this stage, the female weevil chews a minute hole in the grain in which the eggs are deposited. The hole is sealed with a mucilaginous material secreted by the female (Hill, 2008). The eggs are white and oval in shape, measuring 0.7 mm by 0.3 mm, and each female may deposit as many as five eggs per day laying a total of one hundred and fifty to four hundred eggs during its life span (Bosque-Perez, 1992). The eggs hatch into tiny grubs in four to nine days. Larval development last about twenty-five days under favourable conditions of temperature of 30°C and seventy percent relative humidity but under unfavourable environmental conditions, the larval stage may last for up to ninety-eight days (Mattah, 2001). The grub is white in colour with a brown head and strong jaws. Pupation occurs within the grain, and the pupal stage lasts for three to six days. The newly emerged adult remains in the grain for a few days before it leaves it (Hugh, 1988; and Chilio *et al.*, 2004).

Maier (1996), reported that under optimum laboratory conditions of 31^{o}C and fourteen percent fourteen percent moisture, maize weevil takes from thirty to forty days to develop from egg to adult whereas unfavourable conditions such as temperatures above 32^{o}C with less than fourteen percent (14%) maize moisture content it may extend to one hundred and ten (110) days (Kiritani, 1965). Chilio *et al.*, (2004) demonstrated that the weevil is unable to survive at temperatures above 32^{o}C. *S. zeamais* is a small weevil measuring 2.5 - 4 mm long. It has a protruded rostrum or snout, uniformly coloured dark brown or reddish brown, used in chewing and boring into the grain. The prothorax and elytra are densely pitted with rows of microscopic circular holes. The legs are prominent, and the wings are well developed making them good fliers. The larva which feeds in the grain is a white, legless, thick-bodied grub (Kiritani, 1965).

2.8 Insect pest control measures

Botanical insecticides, natural chemical products based on powders, extracts or purified substances of plant origin and physical control methods like manipulation of the temperature and humidity of the storage environment plus grain drying, are topping research on control measures for food storage in Africa.

Chemical control is generally a treatment measure involving the use of insecticides. With the increasing concern about the use of synthetic insecticides, the need to find alternatives that are readily available, affordable, less poisonous and less detrimental to the environment was apparent (Niber, 1994). Plant products and their secondary metabolites are receiving increasing attention in stored product management (Arthur, 1996; Zettler & Arther, 2000; and Haque *et al.*, 2000). The technology is not new as peasant farmers have used it to protect their grains in the small scale and rural settings. Several workers have evaluated the insecticidal, repellent or antifeedant and development inhibiting effects of various plant parts and plant products on *S. zeamais* with varying degrees of success (Obeng-Ofori *et. al.*, 1998; Belmain et al., 2001; Udo, 2005; Asawalam *et al.*, 2006; Arannilewa *et al.*, 2006). In Ghana, Obeng-Ofori and Armiteye (2005) used coconut, groundnut and soybean oil applied at two (2), five (5) and ten (10) ml/kg and Pirimiphos methyl at 1/8 and 1/16 of the recommended dosage and reported significant mortality of *S. zeamais* within 24 hours of exposure compared with untreated controls. Other workers including Owusu-Akyaw (1991) and Cobbinah and Appiah-Kwarteng (1989) have reported the insecticidal, antifeedant and development inhibiting activity of some local plants and plant parts to *S. zeamais*.

Stored maize was treated with permethrin, phoxim, trichlorfon, diazinon, DDT and pyrethroids for seed (Langunes-Tejeda, 1991). Five out of nine plant products namely neem seed oil, jatropha seed oil, Black pepper powder, neem wood ash and ordinary wood ash tested in laboratory experiment were effective in controlling *S. zeamais* (Owusu-Akyaw & Afun, 1988).

2.9 Resistant varieties

Sitophilus zeamais and *Sitophilus oryzae* have also been found to be resistant to some pesticides and Phostoxim as well as to both Malathion and Pirimiphos-methyl (Sayaboe and Aceda, 1990), and to pyrethroids (Fragoso *et al.*, 2003; Ribeiro *et al.*, 2003). Resistance in stored maize to *S. zeamais* attack has been attributed to a number of factors (Ivbiljaro, 2009; Siwale *et al.*, 2009; Arnason *et al.*,1994) reported that some Mexican landraces of maize were resistant to *S. zeamais* and attributed the resistance to the phenolic acid content of the maize. Similarly, Bergvinson (2001) reported that there were strong correlations between the insect resistance, kernel hardness and elevated levels of diphenolic acids located within the pericarp of the kernel. Kernel hardness as a resistance mechanism was only limited by moisture content. Moisture content above less than twenty (16%) percent renders resistant maize genotypes susceptible. In sorghum, the best examples of this process are: shoot fly resistance in landraces cultivated during the post rainy season in India, sorghum midge resistance in genotypes originating from eastern Africa, and head bug resistance in guineense sorghums cultivated in western Africa. This highlights the importance of grain conditioning before storage.

2.10 Traditional methods of insect pest control

The use of traditional stored product protection methods is very popular among small-scale farmers in Africa. The methods are numerous, diverse and widespread in the continent, with regional and country particularities. Tadesse and Eticha (1999) reported 25 traditional management practices for stored maize. Farmers in the North Central Regions of Namibia use traditional methods like ash or leaves in the protection of stored pearl millet (Keyler, 1996). Farmers in Uganda use banana juice, pepper, Mexican marigold (*Tagetes minu*ta) L. and eucalyptus leaves for bruchid control in storage (Giga *et al.*, 1992). Tapondjou *et al.*, (2000), Nukenine *et al.*, (2003) and Ngamo *et al.*, (2007) reported over 20 insecticidal plant species in Cameroon with most of them being employed in storage protection by rural farmers. Animal wastes such as goat and cow urine or dung are also used in the management of storage pests. For example, farmers in parts of Tanzania and the Sahel stored beans in sacks soaked and dried in goat urine which provided protection against storage pests (Gahukar, 1988). Belmain and Stevenson (2001) presented a list of sixteen (16) plants commonly used by farmers in northern Ghana for stored product protection. The leaves, flowers, seeds or roots in whole, decoction, powder extract forms are admixed or layered with the grains. Obeng-Ofori and Armiteye (2005) used coconut, groundnut and soybean oil applied at about three (2.5) and ten (10) ml/kg and Pirimiphos methyl at 1/8 and 1/16 of the recommended dosage and reported significant mortality of *S. zeamais* within twenty-four hours (24hrs) of exposure compared with untreated control. Five out of nine plant products namely Neem seed oil, jatropha seed oil, Black pepper powder, Neem wood ash and ordinary wood ash tested in laboratory experiment were effective in controlling *S. zeamais* (Owusu-Akyaw and Afun, 1988). Other researchers including Owusu-

Akyaw (1991) and Cobbinah and Appiah-Kwarteng (1989) have reported the insecticidal, antifeedant and development inhibiting activity of some local plants and plant parts to *S. zeamais*. For a long time, farmers have continued to select sorghum based on desirability for human consumption and adaptation to their environments (Mann *et al.*, 1983).

2.11 Synthetic chemical methods of insect pest control

The use of chemical insecticides in the form of sprays, fumigant or dusts against grain pests is common in large scale farms. Chemical control is generally a treatment measure involving the use of insecticides. Stored maize was treated with permethrin, phoxim, trichlorfon, diazinon, DDT and pyrethroids for seed (Langunes-Tejeda, 1991). Due to their rapid action, small-scale farmers are also attracted to these chemicals and those who have access to them are beginning to reduce the use of, or even abandon plant materials, which are lower in insecticidal efficacy. The usual chemicals recommended for stored product protection are employed, but also insecticides meant for the treatment of field crops like cotton or those internationally banned like DDT, are used by farmers in countries like Cameroon, Benin, Eritrea, etc. (Haile, 2006). *Sitophilus zeamais* and *Sitophilus oryzae* have also been found to be resistant to DDT and phoxim as well as to both Malathion and Pirimiphos-methyl (Sayaboe and Aceda, 1990), and to pyrethroids (Fragoso *et al.*, 2003; and Ribeiro *et al.*, 2003).

2.12 Econometric models

The basic economic theory of the study is that output, Q is a function of a given variable and fixed inputs, X. this economic theorem can be written in a regression form which is the dependence of a variable on one or more variables (Panneerselvam, 2008) as $Q = f(Xi)$, where Xi is the i^{th} input. Since the second determine the value of grain loss due to insect pests in maize and sorghum in the identified storage structures. It treated as an impact assessment that assumes that storage structures as an intervention, X which influences outcomes of livelihoods such food security (Y) among others. The food security is equal to the quantity of food stored (FS) or farm size, Y which is a function of the quantity of output (Q) produced and output prices (P). This is expressed mathematically as FS = Y = f (Q, P) = P x Q. it can therefore be said that those factors that influence output also influence the value of output (farm income) implicitly.

First, the models necessary for identifying and determining the factors that influence the extent of storage losses by insects to farmers are considered. Though there are different qualitative response/binary choice models that could be employed in this study, the most appropriate models which is the ordered probit/logit was used. Second, the quantitative response model employed in this study to estimate the effect of storage losses on the livelihoods of farmers is the linear regression model. The selected models are discussed below. The model selection was based on the goodness of fit measures such as F-statistic, the likelihood Ratio, the R – squared and the number of significant variables using the t – statistics

2.12.1 The logit and probit models

The logit and probit models specify a non-linear functional relationship between the probability of making a decision such as building good conditioned storage structures by farmers and the various explanatory variables. The logit model has a logistic distribution function and that of the probit has an underlying normal distribution function for stochastic term, E. Given equation (3.2),

$\mathrm{b}\ (\mathrm{I}) = \Phi\ (\Phi X^{!})^{,}$, for a given regressor vector, it is expected that

$$\lim_{\beta' X \to +\infty} \mathrm{prob}(Y = 1) = 1$$

and

$$\lim_{\beta' X \to -\infty} \mathrm{prob}(Y = 1) = 0$$

the standard normal distribution for the probit model is specified as follows:

$$prob(Y = 1) = \int_{-\infty}^{\beta' x} \Phi\,(t)\delta t$$

the logistic distribution for the logit model is specified as:

$$prob(Y = 1) = \varepsilon^{\beta' x}/(1 + \varepsilon^{\beta' x})$$
$$= \Lambda(\beta' X)$$

Where Φ (.) represents the standard normal distribution function and Λ (.) represents the logistic cumulative distribution function.

Given the above therefore,

$$E[Y] = 0[1 - F(\beta' X] + 1[F(\beta' X)].$$
$$= \Lambda(\beta' X)$$

To estimate this model, the maximum likelihood estimator (MEL) is usually used and is specified as:

$$InL = [y_i InF(\beta' X_i) + (1 - y_i)In(1 - F(\beta' X_i)]$$

Empirical studies in several cases have observed that the probabilities given by the two (logit and probit) are similar and can therefore be used interchangeably. However, the theoretical foundation establishes that the differences between the two should not be ignored (Greene, 2003; Cameron and Trivedi, 2005).

The probit and logit methodologies constitute a single possibility when the dependent variable in this case access to good conditioned storage structures is dichotomous. A strictly dichotomous dependent variable is however, not sufficient for examining the extent of access to “good conditioned" storage structures by farmers hence the need for another approach the linear regression model

2.12.2 The linear regression model

A great deal of empirical micro-econometrics research uses linear regression (Cameron and Trivedi, 2005). The simple linear regression model is used to determine the effect of an explanatory variable on an endogenous variable such as income, expenditure or output of an individual, firm or household. It is termed as simple because it consists of only one independent variable and a dependent variable (Ofosu & Hesse, 2008). In the real world situation however, it is rare in economic relationships to see just two variables influencing each other. The dependent variable can be influenced by a number of independent variables. For example, the demand for a commodity such as tea (Lipton) does not only depend on its own price but also on the price of substitutes such as Milo, complements such as sugar and milk among others. In the same manner, the income of an individual or firm is not influenced by only the one input but a number of them. An estimation of the effects of changes in explanatory variables on an endogenous variable requires the use of multiple regression models. The functional form of multiple regression model expresses a linear relationship between the exogenous variables and endogenous variable. The general mathematical form of this regression model is given as:

$$Y = a_o + \sum_{i}^{n} a_i X_i + U_i$$

Where Ù4 and ÙÜ are the y- intercept and slope of the regression model respectively; i = 1, 2, 3. Representing the number of inputs; X is an explanatory variable (input), y is the dependent variable (income, expenditure) and U is the stochastic term. The empirical estimation form of the multiple regression models is given (Thomas, 1997) as

The model is estimated using the Ordinary Least Squares (OLS) estimation method and the parameters interpreted as marginal effects.

According to Armendariz and Jonathan (2005: 2003), to be concrete in measuring the impact of determinants (insect pest and structural) of storage losses and its implication on food security Following this, the effect of storage insect pest in structure of farmers is measured through good storage practices and can be estimated by using the linear regression model (see also Coleman, 1999 and 2003). The study therefore adopted the linear regression model to measure the effects of storage insect pest in the structures of farmers which is the central to their livelihoods development.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology for the study. It describes the diverse methods, procedure and techniques used to gather relevant data for this research. This includes the research design adopted for the collection of data from the population, the study area, population of the study and sampling techniques that were used in arriving at the representative sample. It further highlights the research instrument used for data collection and data analysis.

3.2 Study design

This study adopted a descriptive survey design. The design provided the opportunity for data to be collected through face-to-face interviews by using a questionnaire. The purpose of the descriptive survey design is to observe, describe and document aspects of situations as they occur naturally (Fraenkel & Wallen, 2000). Descriptive survey provides a more accurate picture of events and seeks to explain people’s perception and behaviour on the basis of the data gathered at a point (Osuala, 1993). It must be stated here however that, there are hindrances the survey method could pose considering the fact that it has its own side effects. This is largely because independent variables cannot be manipulated the way they in the laboratory experiment (Wimmer and Dominick, 2000).

The design of the study also involved primary and secondary data collection. The secondary data involved review of literature from journals, text books and newspapers. The primary data was collected with open-ended and close-ended questionnaires which were analysed qualitatively and quantitatively discussed in accordance with the aims and objectives of the study.

3.3 Study Area

The study was carried out in the then Savelugu-Nanton District of the Northern Region. This area covers a land area of 1,790.70 square km and laid within Latitude 9.62 and Longitude -0.83 degrees and with a population of 139, 283 (PHC, 2010). The district was established by PNDC Law 207 under the Legislative Instrument of 1988 when it was carved out of the then Western Dagomba District Council, which included Tolon/Kumbungu and the Tamale Districts and was again separated in 2012 from Nanton to become a Municipality. It shares boundaries with the West Mamprusi District to the North, the Nanton District to the East, Kumbungu District to the West and Tamale Metropolitan Assembly to the South.

Predominantly, agriculture is the mainstay of the economy, and nearly all (97%) of the economically active population (between 15 and 60 years) is involved in farming and mainly at subsistence level. The major food crops cultivated include maize, sorghum, millet rice, and yam, groundnut, cowpea and soya beans but have the potential to increase output if modernized agriculture is effectively practiced. The district is divided into 4 agricultural zones by the MoFA for effective administration. The agricultural sector however encounters problems of food crop production such as unstable food prices, high cost of farm inputs, post-harvest losses and over reliance on rain fed agriculture. Although food price fluctuations could emanate from the rain fed agriculture, inadequate storage facilities and post-harvest losses due to pest infestation pose a serious threat to farmers. The problems of storage force farmers to sell at low prices immediately after harvest due to glut. Food prices are therefore low in the harvest period but high during the lean season. Secondly, farming is mainly rainfall dependent, which is highly erratic thus causing seasonal unemployment, food insecurity and poverty.

3.4 Sample and Sampling procedure

A field survey was done to identify the communities in the area. There are a total of one hundred and forty nine (149) communities in the district out of which active agricultural extension work is carried in twenty-two (22) communities. These twenty-two communities are grouped into four (4) zones; these are the Savelugu East and West, Diare and Nanton zones. Random sampling technique was first used to select four communities out of the twenty-two communities as a representative sample.

Due to financial constraints and distance, two communities were selected from the four zones in consultation with Agricultural Extension Officer. In all, one hundred and eighty-seven (187) interviews quides were administered to both maize and sorghum famers in two communities, (that is Gushie and Kanshegu). A total of One hundred and fifty-five (155) maize farmers eighty-five (85) from Gushie and 70 from Kanshegu) and representing 54.8% and 45.2% respectively were interviewed, while a total of 32 sorghum farmers (16 each from Gushie and Kanshegu) and constituting 50% each were interviewed.

3.5 Determination of sample size

Farmers were sampled and interviewed using the Robert V. Krejcie and Daryle W. Morgan formula of determining sample size as given below:

$$S = X^2NP\,(1 - P)\ \div\ d^2(N - 1) + X^2P(1 - P)$$

Where to participate in the study, Sampling of farmers to determine the sample size for the research

S = required sample size.

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841)

N = the population size.

P = the population proportion (assumed to be .50 since this would provide the maximum sample size)

D = the degree of accuracy expressed as a proportion (.05).

To use the plate 3 at the appendix section, no calculation is needed to determine the sample size to be representative of farmers in the study area. To obtain the required sample size enter plate at N. which is applicable to any defined population. The relationship between sample size and total population is illustrated in the plate below. It should be noted that as the population increases the sample size increases at a diminishing rate and remains relatively constant.

3.6 Research instruments

Questionnaires and Interview guides and Focus group discussions were used as the main data-gathering instrument for this study. Two types of questionnaires were designed. The first part of the study was the use of interview guides to generate information on local grain storage systems, structures, practices and problems from the farmers, and one questionnaire for the Municipal Agriculture Official to answer on the same issues as a key informant.

In order to test the validity of the interview guides and questionnaire for the study, a pre-test was done to twenty respondents comprising of ten (10) maize farmers and ten (10) sorghum farmers from the Municipality but different from the selected ones for the study. These respondents as well as their answers were not part of the actual study process and were only used for testing purposes. After the questions have been answered, the respondents were asked to make suggestions or any necessary corrections to ensure further improvement and validity of the instrument. The instruments were revised based on the suggestions given by the respondents.

Irrelevant questions were excluded and difficult terminologies were changed into simpler ones in order to ensure comprehension.

Subsequent data collection was done through discussions with maize and sorghum groups of farmers depending on the focus of the discussions. Information on problems and constraints in maize and sorghum storage were identified through brainstorming sessions with farmers, a process that was facilitated through the use of a problem pyramid. This visual tool helped farmers with little or no formal education to prioritize the problems identified and establish a hierarchy. The most important problem was represented by the longest rectangle and the least important by the shortest. The rectangles were then arranged to form a pyramid starting with the longest at the bottom to the shortest at the top. Forty farmers from each village were individually interviewed on the main cereals they grew and on the functions of these cereals within their local household food security system.

3.7 Method of data collection

Data was collected through interviews (using interview schedule and interview guides) to elicit information about the storage technologies adopted by maize and sorghum farmers and its effect on household food security. The instruments were designed to collect data on demographic variables and non-demographic variables. The demographic variables include age of farmers, sex, major occupation among others while the non-demographic variable include type of farming operations, problem faced by the farmers in the course of harvesting and postharvest handling of the produce.

Key informants interviews were held with MoFA representatives (also known as supervisors) as well as experienced maize and sorghum farmers and their local leaders. The informants were required to have much knowledge about the village and the farming activities in the study area.

The information obtained from these informants was cross-checked and confirmed using semi-structured interview guide, farm visits and field observations with other farmers in the study area.

3.8 Sources and tools for data collection

3.8.1 Primary Data

Primary data were generated through interviews of maize and sorghum farmers using an interview schedule, and the Assembly members and MoFA representatives (also known as supervisors) through the use of interview guides.

3.8.2 Secondary data

Secondary data for the study were collected from secondary sources such as Journals, past research works, Government records, documented statistics collected from the study area, internet sources and the University Library. This was accomplished through visit to the district assembly and district MOFA and other related sources to conduct interviews.

3.9 Procedure for storage sample collection

Sampling once a month coupled with records of grain consumption and disposal enabled an accurate estimate of the losses over the season to be obtained.

1) At the time of storage;
2) Approximately halfway through; and
3) About a month before the store is emptied.

These samples was taken from the store of farmers and monitored regularly to determine grain moisture content and temperature and to determine the pattern of infestation. Notes were made of the way in which grain is removed and of the pattern of consumption.

Samples of various stored grains were taken for routine examination during the study period. The stored grain was monitored regularly to determine grain insect infestations. A sample stored grain was checked for insects at least monthly from October through December. Particular attention was paid to the grain surface and the central core of the grain mass, but also sample additional locations and depths (Approximately 1 kg sample).

Sample bags containing laboratory samples were closed by knotting the tie ribbons tightly around the bag necks, and secured by attaching metal seals to the tie ribbons after closure. Paper labels were placed inside sample bags before they are closed and sealed, and the bags marked indelibly with simple identification marks. Based on the capacity to infest sound kernels, insects are classified as either primary or secondary. Primary insects are those that make initial attack on fresh grain while the latter are those that feed on grain after it has been initially bored. Damage done by these insects consists of contamination and direct grain loss. Caliboso (1982) stated that a rice weevil can eat 14 milligrams during its developmental period from egg to adult.

3.9.1 Quality loss determination

The samples collected were subjected to physical analysis to determine the quality parameters (% Yellow and % Damaged kernels). Observations were then carried out and proportion of quality loss reported.

3.9.2 Preparing grain sample for testing

The following steps were followed in the preparation of grain samples for testing:

1. Foreign matter and dust were removed from the 1kg sample collected from farmer's store and the foreign materials collected were weighed
2. The insects from the foreign matter were separated and placed in a vial containing alcohol. The insects were separated into adult, larvae and pupae.

3. The moisture content of the clean grain sample was determined.
4. The clean sample was divided into four different containers
5. The germination percentage of the grain sample was determined using the standard testing method
6. 500 kernels of grain were counted and the damaged grain separated from the undamaged grain
7. The damaged and undamaged grain were each weighed to determine the weight of each

3.9.3 Grain quality analysis

In storage loss assessment, gravimetric (count and weight) method which compare the mean weight of damaged and undamaged kernels from within the sample: Anon (1969) was adopted to obtain a rough indication of loss caused by insects. These involve dividing the 1kg grain sample into four (4) different containers, separating the grain into damaged and undamaged and weighing each portion or lot. The percentage weight loss is calculated using the formula below:

$$\text{Weight loss \%} = \frac{UNd - DNu}{U(Nd + Nu)} \times 100$$

Where:

U = weight of undamaged grains

D = weight of damaged grains

Nd = number of damaged grains

Nu = number of undamaged grains

3.10 Data and the Ordered Probit Model results

Using the Ordered probit model, the study included the following explanatory variables age in years, educational level, dummy (1= literate; 0 = otherwise), training, dummy (1 = received training; 0 = otherwise), sun-drying dummy (1 = longer periods; 0 = shorter periods), storage walls, dummy (1 = mud walled; 0 = open walled), storage roof, dummy (1 = grass/aluminium metal roofed ; 0 = Plastic roofed), general storage structure condition, dummy (1 = good; 0 = bad), storage floor, dummy (1 = concrete; 0 = Otherwise), storage floor platform, dummy (1 = yes; 0 = no).

These explanatory variables are used to predict the probabilities of having different storage structures and conditions as shown below.

$$y_i^* = \beta_0 + \beta_1 Age_i + \beta_2 educational\ level_i + \beta_3 training\ received_i + \beta_4 Sun - drying_i +$$

$$\beta_5 Storage\ walls_i + \beta_6 storage\ roof_i + \beta_7 general\ conditions\ of\ structure_i +$$

$$\beta_8 Storage\ floor_i + \beta_9 Strucutre\ platform_i + \varepsilon_i$$

Where

y_i^* = observed and unobserved variables in favour of storage loss

y_i = Postharvest losses at village storage or family granary.
$y_i = 0$ if y □ 0, indicating the farmer recording no storage loss

$y_i = 1$ if $0 < y^* < P\ 1$, indicating the farmer recording average loss

*

$y_i = 2$ if $\mu_1 \leq y^* \leq \mu_2$, indicating the farmer recording high loss

X1 = Age of respondents in years

X2 = Education of respondents in years dummy 1= literate; 0= otherwise

X3 = Training received in years dummy 1= yes received training; 0= otherwise

X4 = Sun-drying in duration dummy 1= many days; 0= few days

X5 = Storage structure walls dummy 1= mud walled; 0= open walled

X6 = storage structure roof dummy 1= zinc/grass-thatch; 0= plastic roof

X7 = General condition of storage structure dummy 1= good; 0= bad

X8 = storage structure floor dummy 1=concrete; 0=wood

X9 = Storage structure platform dummy 1= yes; 0= otherwise

P1 and P2 are jointly estimated threshold values which determine the storage loss of a farmer.

3.11 Data analysis

Both quantitative and qualitative methods were used in the analysis of the data. The qualitative data were mainly collected through the use of interview schedules and observation. The quantitative data were generated statistically using Statistical Package for Social Scientists (SPSS) version 20 and Microsoft Excel (Office 2010). Descriptive statistics were presented using tables, frequencies and simple percentages. The iinferential statistics were generated by running an ordered probit model regression.

3.12 Limitations of the study

The study covered two communities, sampled out of the four (4) agricultural zones because of inadequate finances, transportation due to the long distance nature of the selected communities for the study area and time constraints.

Secondly, some laboratory experiments such as germination test, moisture content determination could not be carried because of time constraints.

Other limitations of the study were the inability of the respondents to keep accurate records of their production activities and for that matter accurate measurement of output and related factors of production was a big challenge. Also because most could not read, much time was therefore taken to explain the purpose of the study in detail to them before they accepted to participate in the study.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents findings of the study in relation to the study objectives. Issues discussed in this chapter included the demographic characteristics of respondents, storage facilities available and used by the farmers, conditions of storage facilities used by the respondents, problems associated with the storage facilities used by the people and the relationship between storage practices and socio-economic characteristics.

4.1 Socio-economic characteristic of respondents

The socio-economic characteristics of the respondents in the study community were categorized according to age, educational status, marital and household status, major and minor occupations. All these variables were investigated to understand their possible influence on the practices and constraints of farmers in the storage and pest management of sorghum and maize.

4.1.1 Age distribution of respondents

The study found the ages of respondents to be relevant to the study objective and therefore investigated it. Conventionally, there is a widespread observation that age of a person wields greater influence on behavioural deposition and capable of ordering economic activities. This viewpoint necessitated an in-depth analysis of age category of respondents and relating it to the interpretation dynamic.

Table 4.1: Age distribution of respondents

Age Range	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
18 – 45	126	81.3	26	81.3
46 – 64	14	9.0	4	12.5
65+	15	9.7	2	6.3
Total	155	100.0	32	100.0

Source: Field survey, 2012

The result show that, the majority (81.3%) of the respondents fell within the age 18 – 45, for both the sole maize famers and sole sorghum farmers as indicated in Table 4.1. Almost ten percent (9.0%) of the respondents fell within the age group of 46 - 64, for sole maize farmers and about thirteen percent (12.5%) for sole sorghum farmers. Finally, it was also found that less than ten percent of the respondent in both the sole maize farmers (9.7%) and sole sorghum farmers (6.3%) were with the age category of 65 years and above.

The age distribution of the farmers attracted the attention of the researcher as age-variation is likely to affect productivity levels, a common belief that, the productivity of a farmer increases with age. For example, a research conducted by Lord kipanidze, (2000), shows that productivity of farmers in the U.S. increases slightly with age and then decreases. For instance, the productivity (yield output) and land size (acreage) of farmers aged twenty-five (25) to forty-five (45) was much higher than those aged forty-six (46) to sixty-four (64), but those farmers that were aged forty-six to sixty-four were more productive than farmers that were under age twenty-five (25). Interestingly, some of the respondents (farmers) were found to above seventy (80 and 84) years of age. Though age wise these people may be considered weak physically, they were still engage in farming activities as their main source of food supply and seed for the next farming season as indicated in (Adetunji, 2007).

4.1.2 Educational background of respondents

Education and farming experience are the important factors that influence decisions. Several studies have shown that improved education and acceptance of knowledge is a policy measure for stimulating local participation in various development and natural resource management (Dolisca *et al.*, 2006; Tizale, 2007). The educational background of respondents was found relevant to the study and was therefore investigated and the results are presented in Table 4.2.

Table 4.2: Educational background of respondents

Educational level	Sole maize farmers		Sole sorghum farmers	
Non-formal	11	7.1	2	6.2
Primary	25	16.1	4	12.5
J.H.S	27	17.4	2	6.2
S.H.S	2	1.3	-	-
Tertiary	10	6.5	-	-
No education	80	51.6	24	75.0
Total	155	100.0	32	100.0

Source: Field survey, 2012

From Table 4.2 above, it was found that, about seven percent (7.1%) of the respondents who cultivated only maize and about six percent (6.2%) of those who cultivated only sorghum had only non-formal education. It was also found that, about sixteen percent (16.1%) of sole maize farmers and about thirteen percent (12.5%) of sole sorghum farmers respectively had Primary education only. About seventeen percent (17.4%) and six percent (6.2%) sole maize and sole sorghum farmers respectively had Junior High School education. The majority of the respondents of sole maize (51.6%) and sole sorghum (75.0%) farmers had no formal education. This outcome had a negative effect on the adoption of storage techniques in terms of practices and management as education, farm productivity; efficiency and management are positively correlated (Jamison & Lau.1980).

Wadud and White (2000), and Rahman (2004) used farmer education as the sole measure of farm human capital. Education gives farmers the ability to perceive, interpret and respond to new farm techniques much faster (Nzomoi *et al.*, 2007; Uaiene *et al.*, 2009). The better educated farmers (6.5% tertiary certificate holders) tend to make better choices of inputs, combine them more effectively and judge the appropriate quantity better. Also, educated farmers are more active information seekers than their uneducated counterparts from agricultural extensions and other training institutions.

4.1.3 Marital status of respondents

Marital status of respondents was deemed relevant, hence it was investigated and the results presented in Table 4.3.

Table 4.3: Marital status of respondents

Marital status	Sole maize farmers		Sole sorghum farmers	
Married	136	87.7	25	78.1
Single	14	9.0	7	21.9
Divorced	5	3.3	-	-
Total	155	100.0	32	100.0

Source: Field survey, 2012

The study revealed that, the majority (87.7%) of the sole maize respondents and the sole sorghum farmers (78.1%) were married. A few of the sole maize farmer (9.0%) respondents and the sole sorghum farmer (21.9%) respondents were single. Less than five percent of the maize farmers (3.3%) respondents reported to be divorcees as indicated in Table 4.3.

4.1.4 Household size of respondents

Table 4.4 presents the results of household status of the respondents. This was found relevant to the study objective.

Table 4.4: Household sizes of respondents

Household size	Sole maize farmers		Sole sorghum farmers	
1 – 5	45	29.0	2	6.2
6 – 10	63	40.6	16	50.0
11 – 15	19	12.3	4	12.5
16 – 20	15	9.7	2	6.2
21 – 25	13	8.4	8	25.0
Total	155	100.0	32	100.0

Source: Field survey, 2012

The study also revealed that, the total number of household members were 1,457 for the sole maize farmers and 406 for the sole sorghum farmers giving an average household size of 9.40 and 12.7 with a standard deviation of 6.6 and 8.1 for sole maize farmers and sole sorghum farmers respectively as shown in Table 4.4.

Marital status and household size are correlated and determinants of food security. From table 4.2 and table 4.3 above, marital status could determine the household size of a population. Married individuals may have larger household sizes than their unmarried counterparts with the exception of divorcees and widows/widowers. The average household size for the study community was 9.4 whilst the national household average was 4.4 (GSS, 2012). Larger household sizes would mean more supply of food. The farmer would have to take adequate measures about food storage to conserve food in order to be able to feed the family even during drought. For small scale farmers, the main purpose of storage is to ensure household food supplies and seed for planting as indicated by (Adetunji, 2007).

4.1.5 Other occupation of respondents

Usually, farmers do not depend on only farming for their survival, given the fact that the study area experiences only one rainy season in the year which is also short as indicated in the profile of the study area. Hence, the other means of survival of the respondents (maize and sorghum farmers) was assessed and the results are presented in Table 4.5.

Table 4.5: Other occupation of respondents

Primary occupation	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Other crop farming	38	24.5	10	31.3
Civil servant	15	9.7	3	9.4
Trading	55	35.5	9	28.0
Fishing	47	30.3	10	31.3
Total	155	100.0	32	100.0

Source: Field survey, 2012

The results show that apart from the cereal farming, the respondents were also engaged in the cultivation of other crops as indicated in Table 4.5. Some of the respondents also reported to be engaged in fishing and trading. A significant proportion of them were also in the civil service.

4.1.6 Grains cultivated and farm size (acreage) used by farmers

Of the estimated total number of farmers who harvested maize and sorghum at the period preceding the survey, the majority (91% of sole maize and 95% of sole sorghum farmers) concentrated on sole crop of maize and sorghum on smaller acreage while the few (9% of sole maize farmers and 5% of sole maize farmers) did otherwise, on varying acreages. Maize and sorghum are the main staple crops that are cultivated extensively in the study area (SND-MoFA, 2011).

4.1.7 Yield per acreage and quantity stored

After establishing the acreage used for the two crops in the study area, the study tried to find out the total amount of these crops were stored between the 2009 and 2012 production years. This is relevant to the study as it answers the main objective of the study.

Table 4.6: Yield per acreage and quantity stored

Sole maize farmers				Sole sorghum farmers			
Year	Acreage	Yield/Acre (in bags)	Quantity stored (metric tons)	Year	Acreage	Yield/ acre (in bags)	Quantity stored (metric tons)
2009	1 - 3	3.0	1.5	2009	1 - 3	1.5	0.5
	4 - 6	7.5	2.2		4 - 6	3.5	1.0
	7 - 10	15	4.0		7 - 10	5.0	2.0
2010	1 - 3	2.5	0.5	2010	1 - 3	1.5	0.5
	4 - 6	5.0	1.5		4 - 6	2.0	1.0
	7 - 10	12	3.0		7 - 10	3.5	2.0
2011	1 - 3	3.0	1.0	2011	1 - 3	1.0	1.0
	4 - 6	5.0	1.5		4 - 6	3.5	1.5
	7 - 10	10	3.0		7 - 10	4.0	2.0
2012	1 - 3	3.5	2.0	2012	1 - 3	2.0	0.5
	4 - 6	7.0	3.0		4 - 6	3.5	3.5
	7 - 10	20	3.5		7 - 10	5.0	2.0

Source: Field survey, 2012

From Table 4.6, the average acreage cultivated by the respondents ranged from 1 - 3, 4 – 6, and 7 - 10 for both sole maize and sole sorghum. The expected average yield for both maize and sorghum per acre is approximately 5.5 bags, with the average quantities stored as 2.9 metric tons and 1.2 metric tons respectively. The stocks found in the stores of farmers in September 2012 were all carried over stock from the 2009 growing season. This is was an indication that, respondents were both small and large-scale farmers. The assumption that grain produced and stored over the four (4) years period (2009, 2010, 2011 and 2012) in the data collected for both sole maize and sole sorghum was confirmed through interviews with farmers. The study acknowledges possible errors resulting from respondents' inability to accurately estimate their land sizes and yields. There is a concern that, the quantities of grain found in household stores do not represent the total production.

4.2 Types of storage facilities available and used by farmers in the study area

Food availability depends on physical access, that is, adequate markets, good roads, reliable vehicles to transport food, and storage facilities. A lack of any one of these items can cause a food crisis. Storage is the act of keeping food for future use, therefore the importance of adequate storage facilities to food security cannot be overemphasized. Table 4.7, gives a breakdown of the type of storage facility used by respondents and the capacities of carriage.

Table 4.7: Types of storage structure used by farmers in the study area

Types of storage structures	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Mud Rhombu	90	57.8	8	25.0
Kamboŋ	24	15.5	15	46.8
Woven basket	25	16.0	2	6.3
Clay pots	8	5.3	5	15.6
Open platform	8	5.3	2	6.3
Total	155	100.0	32	100.0

Source: Field survey, 2012

The study revealed that, the storage facilities used by farmers in the study area are mainly the traditional types, which include the mud rhombu, kamboŋ, calabash/gourd, floor/platform, clay pots, and woven baskets. These are the most appropriate type of storage given the size of their harvest and the cost of silos. Traditional stores are often inexpensive and environmentally motivated.

4.2.1 Mud Rhombus

This structure has some advantages. It takes up small area, easily installing, have beautiful appearance and is able to prevent the damages caused by rodents, insects and molds efficiently. Respondents further indicated that this is specially built from a mixture of clay, cow dung (insect repellent), and dry straws. It consists of a base of stabilized earth resting on large stones, timber or earth on the ground. This structure can also be made of concrete pillars with a dome-shaped roof made of dry straws. The technique of making a dome-shaped roof is not easy to master, and usually has to be done by skilled weavers. A variant has been developed with the roof resting upon a wooden frame, which can be erected by unskilled farmers. This store is associated with dry climatic conditions and has 1,000 - 1,500 kg storage capacity, and specially fit to store maize and sorghum.

4.2.2 Local barn (Kamboŋ)

Storage of grain with this barn is a sort of an ideal method, because this structure is able to keep grain quality stable and also prevent it from insects and rodents infestation. What's more, it cost less to construct, never cover space, and easily accepted by farmers. It stores with little capacity, packing storage is proper because of the convenience of grain convey. This barn is built from bamboo sticks, wood, dry straw and reeds.

This kind of barn is rectangular in shape with dimensions of 2m height, 2m diameter, and has a capacity of 1 to 3 tonnes. The barn body is jointed with 6 piece of prefabricated dry straw mat or board by size of 1 x 2m resting on four-cornered erected bamboo sticks. Then grains are stored in it. The characters of this barn, are good temperature preservation and tightness of grain, drying of maize, sorghum and paddy with low moisture content, and meet to functions of storage.

4.2.3 Pots and Jars

Pots are storage containers in the house and serve notably for the storage of cereal seeds and pulses. This structure is cylindrically constructed with an opening at the top to facilitate loading and unloading and a removable lid. The pot is supported externally by tightened steel wire. Both internal and external surfaces are rendered smooth with cement, and the outside may be treated with coaltar to ensure water-proofness. It is also airtight, convenient to use, well moisture proof and air-proof. The length, width and height can been confirmed according to specific conditions and demand. Bottom of pot has 5-10 cm distance from ground, (1.0m length, 0.5m width and

0.05 m thickness). Pots are inaccessible to rodents, efficient against insects, sealed against entry of water, pots make excellent grain containers. However, they should be protected from direct sunshine and other sources of heat to avoid condensation by being located in shaded and well ventilated places. It has 9 -13 m^3 volume and 3,000 - 6,000 kg capacity

4.2.4 Sacks

Sacks are used to store grains for some time, during this period of storage, precautions have to be taken to ensure the safety of the grain and maintain its quality. The bagged grains are kept off the ground to prevent spoilage by translocating water and or termites. Low platforms, tarpaulins or plastic sheeting are used to serve this purpose; but if there is a risk of damage by rodents or other animals, high platforms fitted with rodent barriers are used. Alternatively, the sacks of grains are placed in rodent proofed barn. The need for chemical methods of pest control should not arise if the storage period is short.

Where sacks are used for domestic grain storage, similar conservation measures should be adopted. However, it will be necessary to employ some form of insect pest control but second-hand sacks are thoroughly cleaned and disinfested before use. Sacks are made from Kenaf fibre, special herb fibre or robes and have a capacity of 80-100kg.

4.2.5 Woven basket

In the study area, farmers used woven baskets for temporal storage. These are small capacity containers placed inside or under the house to store grains either for food or seeds. These baskets have the capacity of 20-40 kilograms and are often made up of woven twigs and reeds. These baskets normally take shape of stake depending upon their size. However, grain stored in them becomes an easy target of rodents, insects, birds and moisture damage. Farmer in the study area as part of their indigenous pest control measures makes minor modifications by plastering the baskets with mud and cow dung to provide strength and protection against insects and rodents entry.

4.2.6 Calabash and bottle gourd

Other temporal storage containers used in the study area are calabash or bottle gourd, also known as opo squash or long melon, a vine grown for its fruit, which can either be harvested young and used as a vegetable, or harvested mature, dried, and used as a bottle, utensil, or pipe. They grow in a variety of shapes; they can be huge and rounded, small and bottle shaped, or slim and serpentine, more than a metre long. They are mostly and mainly used for storing seeds till the next season.

From the findings, it can be concluded that farmers in the study area used mainly the local or traditional storage technology to store their grains. Technology on grain monitoring, ventilation, cereal cooling and low temperature grain storage is applied widely, which have active effect on reduction of grain loss in storage.

4.3 Description of storage structures used by farmers

The effectiveness of storage structures in any farming community is related to the availability and affordability of construction materials as well as the technology and its efficiency.

Table 4.8: Description storage structures used by farmers

	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Roof				
Grass-thatched	102	65.8	20	62.5
Plastic cover	10	6.5	-	-
Metal zinc	43	27.7	12	37.5
Walls				
Woven stalks	15	9.7	2	6.3
Mud	101	65.2	26	81.3
Open wall	39	25.2	4	12.5
Floor				
Concrete	100	64.5	10	31.3
Earth	10	6.5	14	43.7
Wooden	45	29	8	25
Plat formed				
Yes	55	35.5	22	68.8
No	100	64.5	10	31.2

Platform height				
0.5m	21	38.2	24	75.0
1.0m	29	52.7	6	18.8
Over 1.0m	5	9.1	2	6.2

Source: Field survey 2012

For most farmers the dry grains are usually stored in solid-walled silos or bins built with local materials or cement. Nearly all the stores visited in the study area were traditional thatched-roofed, mud-walled granaries with earthen or cemented floors either plat-formed or not plat-formed. The percentage of granaries and the materials they are made-of is presented in the table above.

The majority (65.8%) of sole maize farmers and (62.5%) of sole sorghum farmers roofed their storage with grass thatch as the main roofing material, small proportions, (6.5%) of sole maize farmers also used plastic cover to roof their storage structures and about twenty-eight percent (27.7%) of sole maize farmers used the metal zinc to roof their storage structures. Thatched roofing is the most preferred roofing material in the study areas but roof frames are made of either wood or bamboo.

The main materials used by maize farmers (65.2%) and sorghum farmers (81.3%) for the construction of store walls were mud. About twenty-five percent (25.2%) of sole maize storage structures and about thirteen percent of sole sorghum storage structures were not walled (open walled), and about ten percent (9.7%) of sole maize structures and less than seven percent (6.2%) of sole sorghum storage structures were walled or constructed with woven straws to enhance ventilation. The study revealed that, the main construction material used for the floors of their barns or storage structures include cement for (64.5%) and (31.3%) of sole maize and sole sorghum storage structures respectively. Less than seven (6.5%) and less than forty-five percent (43.7%) of sole maize and sole sorghum structures were floored with mud or earth. Less than thirty percent (29.0%) of sole maize structures and twenty-five percent (25%) of sole sorghum structures were floored with wood. Respondents (farmers) indicated that, the wood used must be well dried and treated with a preservative before it is used to prevent termite attacks.

About thirty-six percent (35.5%) of sole maize storage structures and less than seventy percent (68.8%) of sole sorghum storage structures had platforms. Storage structures with storage platforms varied in heights from 0.5m, 1.0m, to over 1.0m. Fire is usually lighted under sufficiently high plat formed structures for insect control by natural fumigation. The smoke enters through holes in the platform and escapes through the roof. Thus the wall must have few openings, so the structure will function as a chimney.

Farmers in the study area also added that, baskets, earthen pots, empty drums, plastic containers, jute bags and woven grass lined with leaves were used and that most of these smaller storage containers are placed in the storeroom, living room, or kitchen for both short and long-term storage.

The study revealed that their storage facilities were made of plant materials and soil for both short and long-term storage purposes. It was further revealed that the constructions of the facilities were done by the respondents (farmers) because it was easy to do so. The construction materials are easily accessible by the community members.

4.4 General conditions of storage structures used by farmers

The study also assessed the general condition (roofs, walls and floors) of the respondents' storage structures. The percentages of storage structures that were found to have leaking-roofs, damaged walls and both leaking-roofs and damaged walls and cracked floors are presented in Table 4.9.

Table 4.9: General conditions of storage structures used by farmers

Stores	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Leaking roof	50	32.3	5	15.6
Damaged walls	5	3.2	5	15.6
Both (i.e. damaged walls and leaking roof)	29	18.7	-	-
Cracked floors	34	21.9	12	37.5
None	37	23.9	10	31.3
Total	155	100.0	32	100.0

Source: Field survey, 2012

Observations of the conditions of the storage facilities of the respondents revealed that some of the facilities were leaking, having damaged walls and cracked floors as indicated in Table 4.9. The gravity of the deterioration was much and as therefore affected both the quality and the quantities of the items stored. Respondents reported that the deteriorated nature of the facilities allowed pest and moisture to cause destructions in term of grain damages and grain loss.

4.4.1 The effectiveness of the storage facilities

The effectiveness of the storage facilities was investigated by allowing respondents to rank the effectiveness of their storage facilities. The ranking was done from best (very effective) to least (poor) and the results are presented in Figure 4.1.

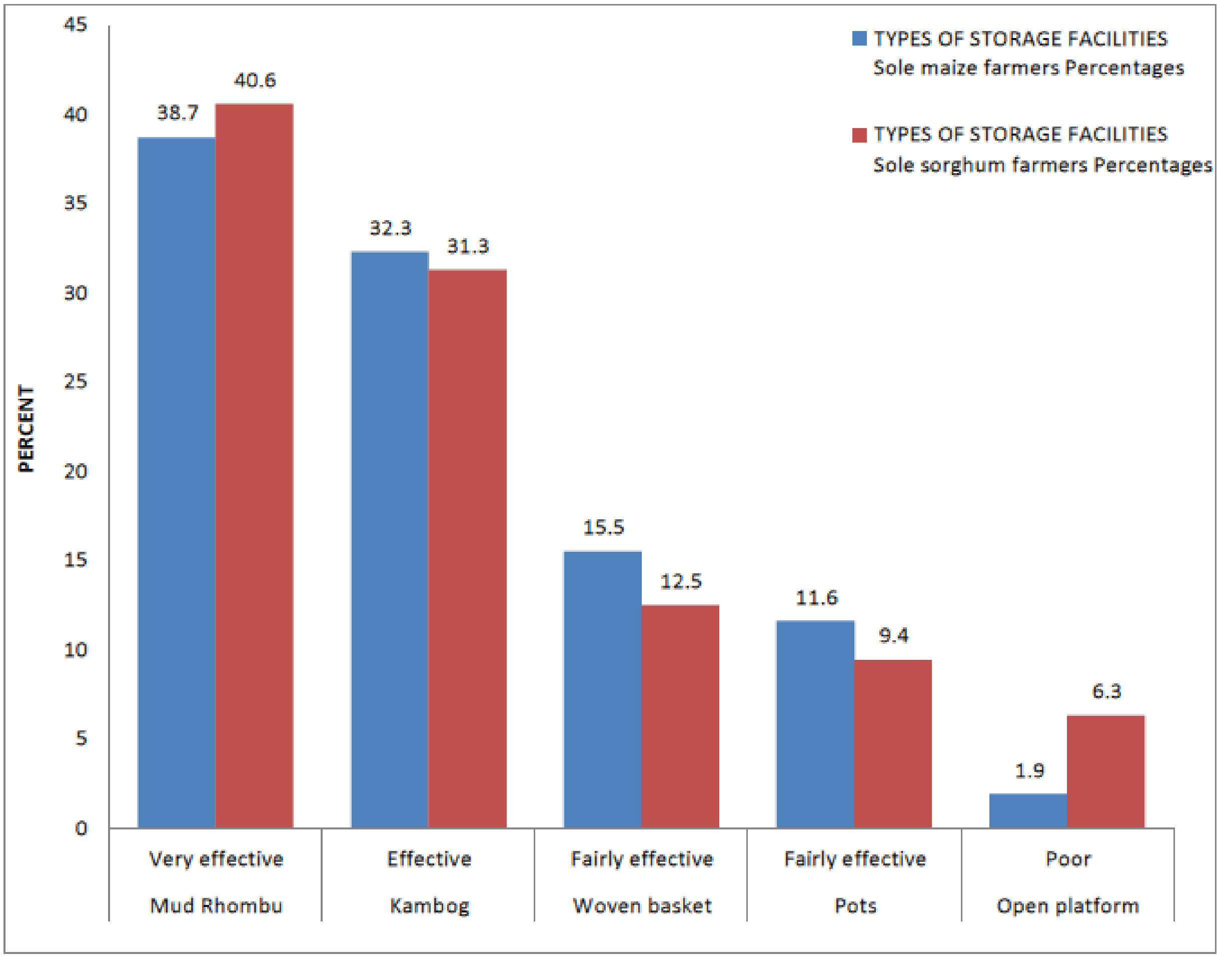

Figure 4.1**: Ranking of storage facilities**
Source: Field survey, 2012

The results show that the Mud Rhombu was ranked "most effective", followed by Kambog (the local barn), woven baskets and pots and the open platform as shown in Figure 4.1. Mud Rhombu emerged as the most effective means of storing both maize and sorghum.

4.4.2 Age of storage structures used by farmers

The age of storage structures is one of the many factors apart from agro-ecological zone, ethnic group, the quantity of commodity stored, the storage condition and the crop variety stored that determine the length of storage. The result from the study is presented in Table 4.10.

Table 4.10: Age of storage structures used by farmers

Age of structure	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
1 -5 years	45	29.0	8	25.0
6 – 10 years	87	56.1	20	62.5
11 and above	23	14.9	4	12.5
Sub-total	155	100.0	32	100.0

Source: Field survey, 2012

Assessment of respondents storage facilities in the Savelugu-Nanton district revealed the length of time that they existed. The respondents revealed that their storage facilities existed from 1 - 5 years for few sole maize (29.0%) and sole sorghum (25.0%) farmers. Most these storage facilities as indicated by sole maize (56.1%) and sole sorghum (62.5%) farmers existed for as long as 6 – 10 years, whiles less than twenty percent of sole maize (14.9%) stores and sole sorghum (12.5%) stores existed for as long as 11 years and above. Respondents explained that given the length of time the facilities have been in use, they have become less effective.

4.4.3 Cost of materials for the construction of storage structures used by farmers

On the average farmers estimated the cost of constructing a storage structure to be within GH¢50.00 to GH¢100.00, while a few farm structures which were constructed cost between GH¢100.00 to GH¢200.00 due to variations in the store type, capacity and local economic situation. It was further revealed that less than ten percent of sole maize farm stores (6.5%) and sole sorghum farm stores (6.3%) were constructed by the farmers themselves. These farmers also estimated that, these stores could last for as long as 20 years if they are well maintained.

The maintenance of storage structures cost farmers' money and time and much of the repair works are mostly done by them. The study found that all of the respondents repaired their own facilities. They found it very difficult to estimate the costs of materials and labour used in the construction of the facilities. Well-maintained storage structures offer a high degree of security against rodents, birds and insects infestation as reported by the respondents.

4.5 Constraints and challenges of storing maize and sorghum

Storage is a way or process by which agricultural products or produce are kept for future use, however, the process is without constraints and challenges. The constraints and challenges were therefore investigated and the results are presented able 4.11.

Table 4.11: Constraints and challenges of storing maize and sorghum

Problems	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Lack of adequate storage facilities	25	16.1	5	15.6
Pest attacks	125	80.6	25	78.1
Climatic conditions	5	3.3	2	6.3
Total	155	100.0	32	100.0

Source: Field survey, 2012

The results show that majority of sole maize farmers (80.6%) and sole sorghum farmers (78.1%) suffer from pest attacks. Some also suffered from lack of adequate storage facilities and climatic factors as shown in Table 4.11. These constraints or challenges identified from the study area are linked to two principal factors, which may be abiotic (granary architecture, humidity and temperature) or biotic (micro-organisms, rodents, birds and insects).

Table 4.12: Loss assessments made by farmers

Rating	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Very severe	57	36.8	18	56.2
Severe	97	51	8	25
Less severe	19	12.3	6	18.8
Total	155	100.0	32	100.0

Source: Field survey, 2012

The results show that, the majority of sole maize farmers (51%) and about twenty five percent (25%) of sole sorghum farmers described their losses as very severe. The majority (56.2%) of the sole sorghum farmers on the other hand described their losses as severe as shown in Table 4.12. These losses reduce the quantity and quality of grains that are stored for future use, thus contributing to food insecurity.

The causes of losses in grain stores are presented in Table 4.13.

Table 4.13: Causes of grain loss in storage

Causes of losses	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Insects	96	61.9	14	43.8
Rats/Mice	10	6.5	1	3.1
Birds	35	22.6	11	34.4
Moulds	14	9.0	6	18.7
Total	155	100.0	32	100.0

Source: Field survey, 2012

The results revealed that, the majority (61.9%) of sole maize storage losses were caused by insects. In the case the sole sorghum farmers, nearly half (43.8%) of the respondents indicated that their storage losses were caused by insects. A few of the respondents (sole maize farmers (6.5%) and sole sorghum farmers (3.1%) also indicated that mice/rat attacks also contribute to their storage losses. These insect pests inflict damage on stored products mainly by direct feeding. The damage created by insects on the grain can affect the farmers because their grain may lose value for marketing, consumption and germination viability.

The key insect pests that were identified by the respondents to be attacking maize and sorghum are indicated in Table 4.14.

Table 4.14: Key insect pests identified by farmers in the study area

Insect pest identified	Sole maize farmers		Insect pest identified	Sole sorghum farmers	
	Frequency	Percent		Frequency	Percent
Sitophilus sp	125	80.6	*Schizaphis graminum*	20	62.5
Sitroga cerealla	15	9.7	*Stenodiplosis sorghicola*	5	15.6
Macrotermes bellicosus	5	3.2	*Antherigo soccata*	5	15.6
Periplaneta americana	10	6.5	Leaf- and panicle Feeding caterpillar	2	6.3

Source: Field survey, 2012

The key store insect pests that were identified by the respondents as attacking maize were sitophilus *sp* Sitotroga *cereallla* Macrotermes *bellicosus* and *Periplaneta americana*. For sorghum, some of the insect pests identified by the respondents were *Schizaphis graminum*, *Stenodiplosis sorghicola*, *antherigo soccata* e.t.c. These insect pests inflict damage on stored products mainly by direct feeding. The damage created by insects on the grain can affect the farmers because their grain may lose value for marketing, consumption and germination viability.

Table 4.15: The effects of insect pest infestation in storage

Rating	Sole maize farmers		Sole maize sorghum	
	Frequency	Percent	Frequency	Percent
Very severe	24	15.5	4	12.5
Severe	92	59.4	20	62.5
Less severe	39	25.2	8	25
Total	155	100.0	32	100.0

Source: Field survey, 2012

The results show that, the majority of sole maize farmers (59.4%) and sole sorghum farmers (62.5%) indicated that the effect of insect pest infestation on their produce as severe. A few sole maize farmers (15.5%) and sole sorghum farmers (12.5%) indicated that, the effect of pest infestation on their produce was very severe while a few others of sole maize farmers (25.2%) and sole sorghum farmers (25%) felt the effects of insect pest infestation on their stored produce was less severe.

4.6 Pest control measures

Insect pest inflict damages to grains in store, hence the study attempted to find out how respondents controlled their grains in store. The results are presented in Table 4.16.

Table 4.16: Pest control measures used by farmers in the study area

Pest control measures	Sole maize farmers		Sole sorghum farmers	
	Frequency	Percent	Frequency	Percent
Sun – drying	55	35.0	15	46.8
Remove and destroy infested grains	10	13.0	2	6.3
Admixing with ash	20	6.5.0	5	15.6
Others (Inorganic chemicals)	60	39.0	8	25.0
Total	155	100.0	32	100.0

Source: Field survey, 2012

The control measures or techniques practiced by farmers in the study area were reported to begin with the observation of the crop stored to see if there are signs of infestation. The results of the observation then serve as a basis for determining the next approach to be adopted. Close to fifty percent of sole maize farmers (35.0%) and sole sorghum farmers (46.8%) reported to have re-dried their grains and re-stored, as indicated in Table 4.15. The results also showed that a few of sole maize farmers (6.5%) and sole sorghum farmer (6.3%) identified and remove the infested grains from the stored grains.

4.7: Determination of loss during storage (samples taken from stores by researcher)

A random sample of between 100-1000 grains was taken and the number of bored grains is counted to determine insect pest infestation. This was done a few days after sampling. The insect species that were found in the sampled maize grains were the *Sitophilus sp* (23 adults, were counted). *Sitroga cerealla* (10 adults counted), *Macrotermes bellicosus* (2 adults were counted at the point of sample collection)*, and Periplaneta Americana* (3 adults were also counted at the point of sample collection). The first two insects were observed from the larvae, nymph and adult stages of their life cycle. The larvae were observed in almost all sampled grains when split open, with some eggs also observed. The larva causes greater damage to produce both in quantitative and qualitative terms as they bore into and feed inside of the grain and grow to mature before they come out as adult insects. This behavioural pattern of the insect's larva results in weight loss, quality loss, nutritional loss, seed viability loss and contamination of produce with their exuvae, frass and elytra. The adult insect causes light or no damage at all to grain.

For the estimated loss or damage, maize recorded about two percent (1.9%) for a total of (155000) grains counted, 3000 grain recorded damaged multiplied by hundred. Sorghum recorded about one percent (0.63%) loss, for a total number of 32000 grains counted, 200 grains were counted damaged.

4.8 Visual Observation of Storage Losses Causes

Conditions of structures used for storage of produce have an important effect on produce quality, quantity and subsequent build-up of insect populations. Visual observation in the study area showed that most storage structures were unclean, which suggests that, the farmers do not clean their storage structures before putting in the grains. Further observations also revealed a consistent poor maintenance and unhygienic practices among the aged farmers in the study area compared to the younger counterparts which is consistent with Ebewore *et al.*, (2013). Some of the structures observed also showed leaking-roofs damaged or cracked walls or both, holes of insects and dead insect debris. These problems with storage practices have a direct relationship to storage losses. Many authors, (Bell, 1996; Ngamo, 2000; Hoogland and Holen, 2001) have contended that a major cause of losses in traditional granaries is the lack of hygiene. They explain that at the time of filling the storage structure with newly harvested grain, the residues of old grains that are not always completely removed and serve as a source of infestation for new grain. These impurities can attract pests from the exterior. Even though the farmers are aware that prior to storage the grains should be adequately dried or kept well ventilated during the storage period to prevent spoilage, if the grain is dry (less than 12%) moisture content, there is usually no problem with this kind of storage.

The traditional storage systems and practices used by the farmers have evolved over many generations and have been able to keep grains cool, dry and safe from pest attacks. But despite adaptations, moisture and pests often find their way to the stored grains, so farmers have to ensure good grain conditions and quality through direct sun-drying, smoking or admixing with ashes and plant materials.

4.9 Socio-economic determinants of storage habit of farmers in the study area

Some socio–economic factors determine the type and effectiveness of storage structures and practices that the farmers use in the study area. These were evaluated with the use of profit model and the result is presented below in table 4.16, 4.17and 4.18 below.

Tables 4.16 and 4.17 give the results of the maximum likelihood estimation of the ordered probit model and coefficients; Table 4.17 shows the marginal effects for all levels of the dependent variable (assessment of loss). What makes the ordered probit (ordered logit) different from the basic binary models is that it gives effects of changes in the explanatory variables on all the observed levels of the dependent variable. It should be noted that being a limited dependent variable model, we are more interested in the marginal effects than the coefficient (Greene, 2003). In Table 4.16 the threshold parameters (P^1 and P^2)) are reported. These jointly estimate the threshold values which determine the storage loss of a farmer.

Table 4.17: Summary statistics

Variable	Mean	Std. deviation	Minimum	Maximum	Total observation
Age	39.61	16.65	20.00	84.00	155
Educational level	4.39	1.86	1.00	6.00	155
Household size	9.40	6.62	1.00	25.00	155
Drying	2.65	2.29	1.00	8.00	155

Source: Field Survey, 2012

The summary statistics of continuous variables of the study showed that the mean age of the farmers was found to be 39.61 years, which proved to be statistical insignificant. The mean average of farmers, who had formal education, was found to be 4.39. With regards to household sizes, average household size of 9.4 people. Larger household is generally associated with a greater labour force being available to the household for timely operation of post-harvest activities. The finding that farmers have larger household size positively influences the decision of farmers to protect their stored grains from loss; this is because there is enough labour to carry out annual repairs and maintenance of storage structure, good hygienic conditions, enough and adequate drying of grain to prevent infestations to insect pest.

Table 4.18: Marginal Effects of the explanatory variables on the Dependent Variable

Variable	Beta	Coefficient	Std. error	t-ratio	p > t
Constant	Na	3.789	0.829	4.571	0.0000
Age	Ni	-0.056***	0.010	-5.605	0.0000
Educational level	N2	0.046	0.063	0.729	0.4659
Training	N3	-0.331	0.292	-1.133	0.2574
Drying	N	0.1268*	0.051	2.509	0.0121
Storage walls	N	0.613*	0.287	2.134	0.0328
Storage roof	N	-1.9296***	0.321	-6.007	0.0000
General condition of structure	Ng	-.5286*	0.293	-1.803	0.0714
Structure floor	N	-1.0631***	0.265	-4.006	0.000
Structure platform	N	-.223	0.257	-0.871	0.3837
MU (1)		2.517	.272	9.262	.0000
Chi square		113.7336		(9)	
Note:	Dependent variable: Assessment of loss No. of observation= 155 Degrees of freedom= 9 Log likelihood function and restricted log likelihood are -93.27946 and -150.1462 respectively McFadden Pseudo R-squared = .3787427 Prob > chi^2 = 0.000				

Marginal effects are computed at the means of the independent variables

Ordered logistic regression, like binary and multinomial logistic regression, uses maximum likelihood estimation, which is an iterative procedure. The first iteration (called iteration 0) is the log likelihood of the "null" or "empty" model; that is, a model with no predictors. At the next iteration, the predictor(s) are included in the model. At each iteration; the log likelihood increases because the goal is to maximize the log likelihood. When the difference between successive iterations is very small, the model is said to have "converged", the iterating stops, and the results are displayed. The final log likelihood (-150.1462) can be used in comparisons of nested models. Also at the top of the output we see that all 155 observations in our data set were used in the analysis. The likelihood ratio chi-square of 113.7336 with a p-value of 0.0000 tells us that our model as a whole is statistically significant, as compared to the null model with no predictors. The McFadden Pseudo-R-squared of 0.3787427 is also given. Scaled R-squared, a nonlinear transformation of the constrained and unconstrained maximum likelihood values, is a good measure of fit. It is bounded within zero and one like ordinary R-squared in classical regression analysis (Estrella, 1998). A value of a 0.379 is considered satisfactory for a data set of 155 farmers. The probability value of 0.000 for the likelihood ratio indicates that the explanatory variables used in the probit model are appropriate.

Table 4.19: Marginal Effects of the explanatory variables on the Dependent Variable

Variable	Loss= no loss	Loss= average loss	Loss= high loss
Age	0.0197	-0.0167	-0.0030
Educational level	-0.0161	0.0136	0.0025
Training	0.1085	-0.0862	-0.0223
Drying	-0.0443	0.0375	0.0068
Storage walls	-0.2259	0.2005	0.0255
Storage roof	0.6547	-0.5653	-0.0894
General condition of structure	0.1800	-0.1486	-0.0314
Structure floor	0.3301	-0.2445	-0.0856
Structure platform	0.0777	-0.0654	-0.0123

Marginal effects are computed at the means of the independent variables

Source: Field Survey, 2012

Maximum likelihood estimation results of the ordered probit model, showed that age, sun-drying, storage structure walls, storage structure roof, including general conditions of structure, and storage structure floor, positively or negatively influenced the dependent variable. The positive sign observed in the determinants (age, Sun drying duration, Storage walls) of grain loss assessment means that, any of the variables will have a positive effect on loss assessment and this will lead to a corresponding increase in grain loss. However, whereas the negative sign of the significant determinants (storage roof, general condition of storage structure, and storage floor) of grain loss assessment means that the determinant variables will have a negative effect on loss assessment (no losses recorded) and this will lead to the corresponding decrease in loss.

Theoretically, the insignificance of the education, training, and storage structure platform, contribution to grain loss assessment means that, these variables will neither have a positive or negative effect on grain losses, other things being equal.

Table 4.20: ***A priori expectation***

Variable	**Description**	***A priori* expectation**
Age	Negative and significant	Did not meet the apriority expectation. From the results, older farmers had greater grain loss than their young counterparts
Education	Not significant	-
Training	Not significant	-
Sun drying duration	Positive and significant	The greater the number of drying days the greater the grain loss. Did not meet our *a priori* expectation
Storage walls	Positive and significant	Rather storage structures that had walls had greater loss. Did not meet our *a priori* expectation.
Storage roof	Negative and significant	Storage structures that were roofed with grass or zinc had smaller probability of grain loss. Met our *a*

		priori expectation.
General condition of storage structure	Negative and significant	The better the general condition of the storage structure, the smaller the probability of grain loss. Met our *a priori* expectation
Storage floor	Negative and significant	Storage structures whose floors were concrete had smaller probability of grain loss. Met our *a priori* expectation.
Storage floor platform	Not significant	-

Source: Field survey, 2012

4.10 A summary of definitions of model variables and *apriori* expectation signs of coefficients are below

Age of farmer: Age in years is a continuous variable. This variable was found negative and significant in the model on the dependent variable. This meant that older farmers were more likely to register low grain losses than their younger counterparts. This is contrary to the findings in the study, which shows that, aged farmers are less effective in their storage habit due to the fact that the older farmers shy away from barn and platform construction. Such farmers will rather resort to the use of ineffective storage facilities and storage method which does not cost much. This did not meet the apriority expectation.

Sun-drying duration: Sun-drying dummy was found to have a positive and significant influence or association on the dependent variable; the greater the number of drying days the greater the grain loss. Greater number of days of sun-drying is significant at 10% given the probability value of 0.0121. Higher temperature and moisture content values of grains favours insect and fungus development and a decline in the germination capacity of the grains as indicated by (Hayma, 2003). Insects can live and reproduce at temperatures between +15°C and +35ºC. On the contrary, low humidity slows or even stops their development, and a low supply of oxygen rapidly kills them. This did not meet our *a priori* expectation.

The storage structure roof of farmer's structure: This was found to have a negative and significant influence on the dependent variable. Storage structures that were roofed with grass or zinc had smaller probability of grain loss. This met our *a priori* expectation. This result was significant at 1% with a probability value of 0.000. Storage structures that were roofed with grass or zinc had smaller probability of grain loss. Storage structure that are roofed with grass-thatched or aluminium metal depends on the farmers' economic strength. Aluminium or grass-thatch provide adequate roofing and are better used than corrugated iron to avoid rising of temperature and controlled ventilation. The combined attack by insects and mould, rapidly deteriorate the stored produce quality. Heating leads to moisture condensation in cool areas within the grain mass. This in turn encourages further fungal growth and insect infestation as indicated by (Appert, 1987; Imura and Sinha, 1989).

Storage structure walls: Storage structure walls were found to be positive and significantly influence the dependent variable. Storage structures that had walls had greater loss. This did not meet our *a priori* expectation. Losses in stored grain are determined by the interaction between the grain, the storage environment and a variety of organisms. The variable is significant at 10%

given the probability value of 0.0328. This is contrary to the research findings that properly built walls with no cracks or holes to discourage insects' pest infestation. Cracked walls serves as hiding holes for insects hibernating and they can re-infest the new grains in the same store and resume feeding. This is contrary to the research findings that mud walls are the most suitable if properly built with no cracks or holes to discourage insects, as insects can hibernate or even continue to feed on wooden structures of the store or hide between holes and cracks in the walls. They can then re-infest the new crop in the same store and resume feeding.

Storage structure floor: storage structure floor of the farmers store was found to have a negative and significant influence on the dependent variable. Storage structures that were concrete floored had smaller probability of grain loss than structures that were floored with wood. This met our *a priori* expectation. As this was expected to have a positive effect on their food store; it was measured as a dummy. Structures that are generally not hermetically sealed give room for pests to make their way into the structures but when constructed of plant materials, rodents easily destroy the structures and favour other sources of infestation as indicated by (CIRAD, 2002).

General storage structure conditions of the farmers' store: This had a negative and significant (10%) association on the dependent variable with a probability level of 0.0714. The better the general condition of the storage structure, the smaller the probability of grain loss. This also met our *a priori* expectation. Clean and hygienic structures protect the seed from external insects and preserve the seed. Many authors have contended that reinfestation of the new grains from the old grains is due to lack of hygiene as indicated by (Ngamo, 2000 and Hoogland & Holen, 2001). At the time of filling the storage structure with newly harvested grains, if the residues of old grain are not completely removed, it serves as a source of infestation for new grain. These impurities can attract pests from the exterior as indicated by (Haile, 2006).

4.11 Implication of grain losses on food security

Based on the findings outlined above, one can safely argue that storage pests do have an effect on food loses in the study area and by extension very serious implications on food security. Months of inadequate household food provisioning has been defined as the time between stock depletion and the next harvest (Bilinsky and Swindale, 2007). It is usually used as a measure of food insecurity in a highly subsistence-oriented area where production is primarily for home consumption and households do not make significant sales or purchases in the market.

Maize and sorghum are the staple food of the indigenes n the study area and are used for a variety of meals such as Tuo Zafi (TZ), the main food eaten and on a daily basis and also for social events such as weddings, funerals and Hausa koko (porridge) taken as breakfast and for sale to the public. Maize and sorghum are also sold to generate income to meet other social and economic needs.

Food availability might not be a problem, but the year on year quantity and quality might be. The Northern Region Agricultural Development Unit (NRADU) of the MoFA`s report for 2009 showed that northern region suffers food shortage for 3 months for maize and 5 months for sorghum annually. For an individual to have a healthy life, he/she needs to eat a healthy diet and on a regular basis The health implications from this are serious as farmers and women and girls migrate during this lean period to the south of Ghana to do menial jobs in order to send money home for food and other necessities. Storage pests are known to eat away the part of the grain that is nutritious, the embryo has protein and so what is left after pest attack is starch and oils.

This makes the food not be balanced nutritionally and so will not be healthy. The pests also contaminate the grains with their faecal and urine waste and dead parts thus reducing the quality of the food and cause malnutrition, which can also be devastating for children, for example stunted growth and mental retardation. Malnutrition undermines economic growth and reduces the productivity of people who try work their way out of poverty, according to Feed the Children, an international Non-Governmental Organisation. The maize or sorghum that is milled for TZ is not usually washed before milling into flour. These contaminants by insects and fungus will predispose the household to sickness.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This section presents a summary of the study, conclusions and policy recommendations. The study was conducted to investigate the practices and constraints of farmers in the storage of maize and sorghum in the Savelugu-Nanton district of Ghana. The agricultural engineer will be mostly interested in losses during combine harvesting, threshing, drying and handling. An entomologist would be mostly interested in losses due to insects while a nutritionist would be mostly interested in losses during processing.

5.1 Summary of findings

The study was carried out in the Savelugu-Nanton district in the Northern region of Ghana. The main objective of the study was to assess the practices and constraints of farmers in the storage and insect pest management of sorghum and maize. The purposive and simple random sampling techniques were used to select the community of study and the sample for the study. The sample size for the study was 155 maize farmers and 32 sorghum farmers. The qualitative and quantitative methods of data analysis were employed to analyse data collected for the study. The qualitative aspect involved the use of frequencies and tables whiles the quantitative involved the ordered probit regression model.

Farming is the mainstay economy of the people of the Savelugu-Nanton district, with the district recording a vibrant productive age group ranging between twenty-five to sixty-five, with a majority of the respondents being uneducated among others. The majority of farmers store grains in traditional granaries which are flawed by structural and functional inadequacies as indicated by farmers in the study area which could lead to food insecurity. Storage pest problems were also indicated as other factors affecting storage in the study area, with losses being on the high side for insect pest. Sampled maize grains found insect species such as *Sitophilus sp*, *Sitroga cerealla*, *Macrotermes bellicosus and Periplaneta Americana*, infestations in these traditional granaries is the lack of hygiene, these impurities can attract pests from the exterior. Structures had problems of leaking-roof, damaged walls or both. These problems with storage practices interestingly could be related to storage losses caused by insect infestation. Current control strategies of post-harvest losses in maize and sorghum include proper conditioning of grain by sun drying to acceptable moisture content. Other measure were the use of both traditional storage measures such ashes, neem leaves, oil and smoke and exotic methods such as the application of fumigants and insecticides.

5.2 Conclusions

In this study, an assessment of storage practices of farmers and food security in the Savelugu-Nanton district was carried out. In terms of farming populations, the study area has a vibrant farming population with a mean age 39 years.

The study established that the major storage facilities available to farmers are the traditional types such as the woven baskets, Kambog, mud rhombu, platforms, floor and bag. These traditional storage facilities have been found to be ineffective and therefore lead to loss of grains thereby resulting in food insecurity in the area. It was also discovered that inadequate facilities, poor record keeping and insect pest are the major problems of storage in the area. Moreover, some socio-economic factors had considerable influence on the storage practices of farmers in the study area.

5.3 Recommendations

On the basis of the findings of this study, these recommendations are made**:**

- The Government should provide farmers with modern storage facilities such as silos and bins.
- The Government should provide farmers with effective pesticides and insecticides that will help to reduce crop and grain losses at storage.
- The Ministry of Food and Agriculture should provide proper education of the farmers about improved methods of storing their crops.

For better storability and quality produce, farmers are advised to:

- Harvest grain at the correct time, i.e. not too early and not too late (1 to 2 weeks after physiological maturity).
- Dry grains to safe moisture content before storage (12 – 15% for all cereals)
- Use proper threshing/shelling methods (avoid beating grain such as maize with sticks. It is better to shell with the fingers or appropriate device).
- Disinfect grain of insect pest before and during storage when necessary.

If these recommendations are implemented, the storage problems and the resultant food insecurity will be ameliorated.

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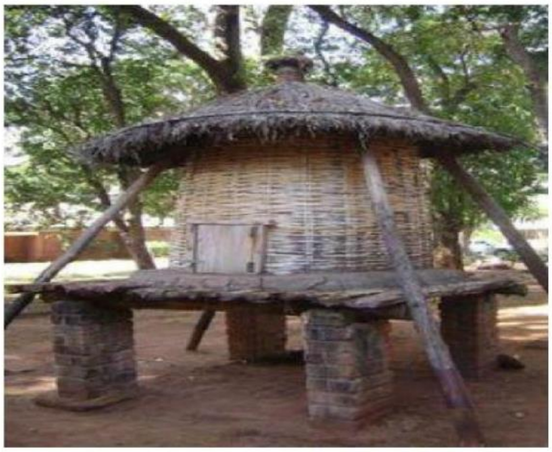
APPENDIX 1

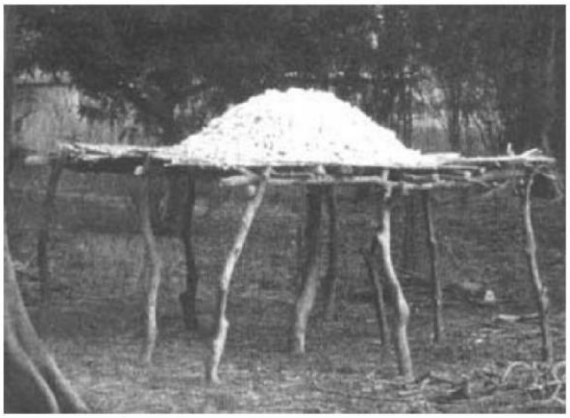
Plate 2.0: Common storage structures in used in the Study Area (Ghana)

Kambog



Modern Woven Basket

Traditional-mud-and-thatch-structure-seed-storage



Open Platform

Woven Basket

Mud Rhombu

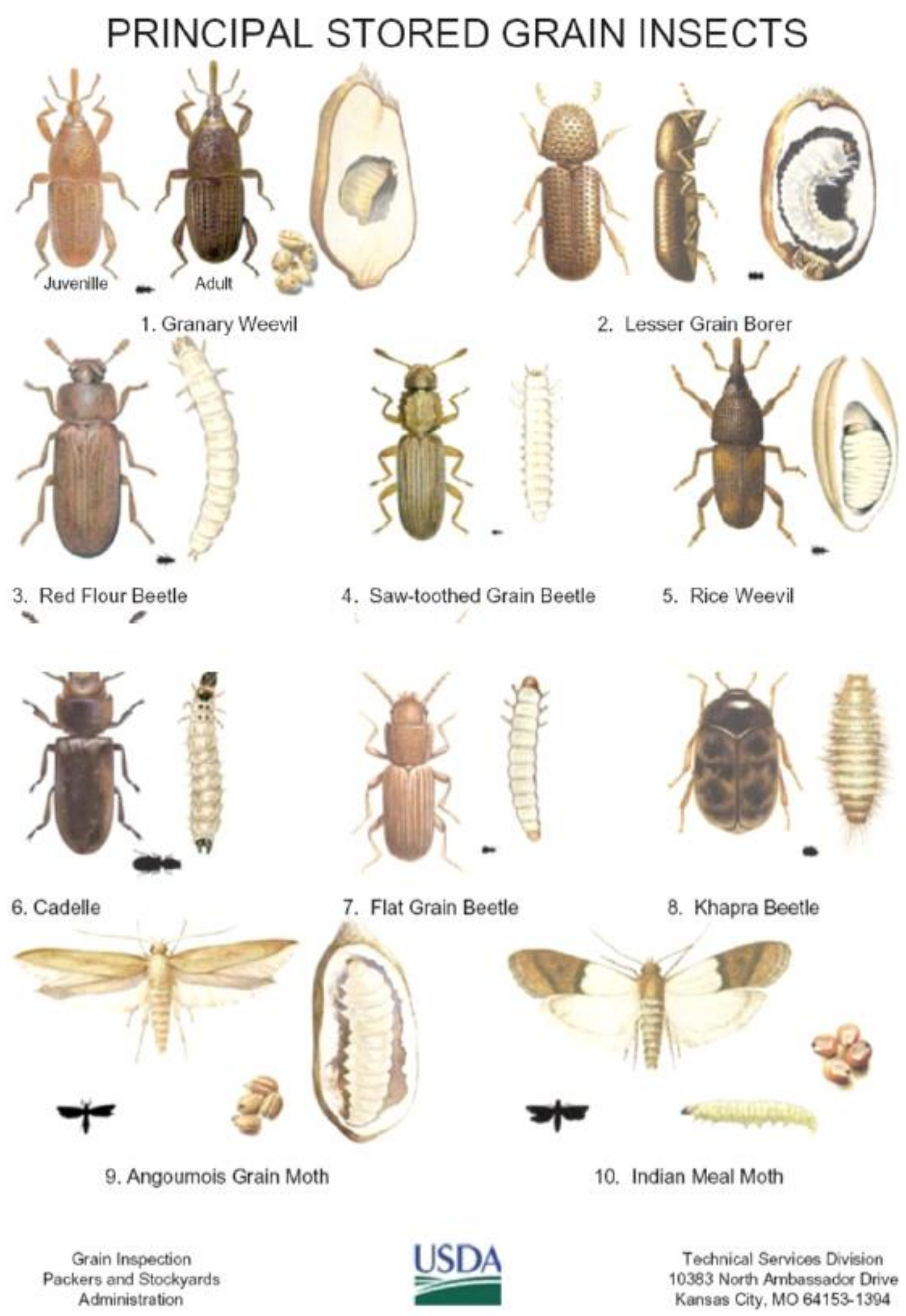
APPENDIX 2 Common traditional storage structure in the study area and its contents

A: traditional storage structure

B: Opening into the structure

C: the inside of the structure

APPENDIX 3


PRINCIPAL STORED GRAIN INSECTS
Juvenille
Adult
1. Granary Weevil
2. Lesser Grain Borer
3. Red Flour Beetle
4. Saw-toothed Grain Beetle
5. Rice Weevil
6. Cadelle
7. Flat Grain Beetle
8. Khapra Beetle
9. Angoumois Grain Moth
10. Indian Meal Moth
Grain Inspection
Packers and Stockyards
Administration
USDA
Technical Services Division
10383 North Ambassador Drive
Kansas City, MO 64153-1394

APPENDIX 4

TABLE 1

Table for Determining Sample Size from a Given Population

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—N *is* population size.
S is sample size.

APPENDIX 5

QUESTIONNAIRE TO Investigate the Practices and Constraints Of Farmers in the Storage and Management of Maize and Sorghum in the Savelugu-Nanton District Of Ghana

Form 1

Questionnaire Number …………… Enumerator's Name ……………………………………

Community…………………………… Cell Phone Number (If any)……………………………

Socio-demographic characteristics of respondents

1. Age ………………………………………………………………………………………………

2. Educational level:

a) Non-formal education [ ] b) Primary [ ] c) Middle/JHS [ ] d) S.H.S [ ] e) Tertiary [ ] f. None [ ]

3. Marital status:

a) Married [ ] b) Single [ ] c) Divorced [ ] d) Separated [ ] e)Widowed [ ]

4. Family size ……………………………………………………………………………………

5. Major occupation ………………………………………………………………………………

a) Minor occupations ……………………………………………………………………………

6. Grain type …………………………………… Capacity ……………………………

Form II (a) Description of storage structure

7. **Storage structure**

Roof/lid: a) grass-thatched b) palm-thatched c) plastic cover d) metal

Walls: a) burnt bricks b) woven basket c) mud d) crib e) open wall

Floor: a) concrete b) earth c) woven basket d) wooden

Platform: a) yes b) no how high? c) 0.5m d) 1.0m e) over 1.0m

8. **General condition of structure**

a) Leaking roof b) damaged walls

very good ii) good iii) fairly good iv) poor

9. **Cost of structure**

How old is the structure? ....Cost of labour............................

Cost of materials...................................

10. **Maintenance**

How often do you repair grain storage areas?

Roof: a) every year b) every 2 years; by whom? c) Man d) woman

Walls: a) every year b) every 2 years; by whom? c) Man d) woman

Form II (b) Production

Acreage and grain stored

Crop type stored	Acreage			Grain
	2010	2011	2012	Quantity kg/tins
Maize	....	....	....	....
Sorghum	....	....	....	....

Farmer’s assessment of loss (ask female members if possible)

Maize a) very severe b) severe c) less severe

Sorghum b) very severe b) severe d) less severe

Causes of loss: a) insects b) rats c) moulds d) birds

Pest control measures:

a) Sun-drying

b) Removal of infested grain from store and destroying it

c) Admixing with ash and other plant materials

d) Smoking

e) Others (specify)

Grain stored

Variety: ....

Date harvested ....

Number of days drying

Grain condition (evidence of damaged)

( ) insects ( ) rats ( ) moisture/moulds ( ) birds

Training Received

Have you received any training in handling pests or conserving food?..

If yes, from which organisation? ....

Was it beneficial? ....

Would you want to receive more training? ....

Form III: Determination of loss during storage

Ref No Date

Farmer's name ________________________Village

Store type______________________________

Grain type________________________Capacity

Sample: How collected____________________

Quantity of grain removed:

First visit

Second visit

Weight of sample

Weight of foreign matter percent foreign matter __________________

Insects present

Species	Adults	Larvae	Pupae

% Moisture content (i) ____________ (ii) ______________Average _____

Number of damaged (i) _______ (ii) _______ Average___________

Number of undamaged (i)________ (ii) __________ Average ________

Weight of damaged (i) ________ (ii) __________ Average __________

Weight of undamaged (i) ________ (ii) __________Average _________

% weight loss: __________

EFFECTS OF INSECT STORAGE PESTS ON FOOD SECURITY

1. What are the main food crops you cultivate?

2. Is the grain cultivated meant for the house or for sale?

3. A. Are the farmers able to meet their food needs throughout the year

B. If no why?

4. What are the main challenges to the attainment of this?

5. How do the farmers store their food crops? 1. On the cob [ ] 2. Shelled [ ]

6. Where do they store the crops? 1. In the barn [ ] 2. In their rooms [ ]

7. Do they experience problems with storage pests with the cereals? 1. Yes [ ] 2.No [ ]

8. If yes, what kind of storage pests do the farmers have problem in the district?

9. At what stage of the storage does the problem occur? 1. On the farm [ ] 2. In storage [ ]

10. Can you estimate the loss?

11. What do the farmers do to protect their produce against these storage pests?

a .

b .

c.

d .

12. What kind of materials do they use to construct the storage structures?

13. Are the structures able to protect your crop against storage pests?

14. Yes [ ] 2. No [ ]

15. If no, what should be done to make the structures more effective in protecting the crops of farmers?

16. What recommendations do you have that would ensure sustainable food security in the district?