Farming System Characterization, and Temperature and Relative Humidity Suitability for Maize grain storage structures in Selected Districts of Jimma Zone, Southwest Ethiopia

MSc Thesis

SHIFERAW DIRIBA DANNO

JIMMA, ETHIOPIA

June 2017

Farming System Characterization, and Temperature and Relative Humidity Suitability for Maize grain storage structures in Selected Districts of Jimma Zone, Southwest Ethiopia

MSc Thesis

Shiferaw Diriba Danno

A Thesis

Submitted to School of Graduate Studies of Jimma University College of Agriculture and Veterinary Medicine to Department of Natural Resources Management, in Partial fulfillment of the Requirements for the masters of Science in Natural Resources Management (Specialization in Forest and Nature Conservation)

Jimma, Ethiopia

June 2017

DEDICATION

To my father; Diriba Danno, for his love and affection

STATEMENT OF AUTHOR

First, I declare that this Thesis is my original work and all sources or materials used for this Thesis have fully acknowledged. This thesis having been submitted in partial fulfillment of the requirements for MSc degree in Natural Resources Management at Jimma University College of Agriculture and Veterinary Medicine and is deposited in the University Library to be made available under the rules of the library. I declare that this thesis not submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate. Brief quotations from this Thesis are allowable without special permission if the source accurately acknowledged. Requests for permission for comprehensive citation from, duplicate of this manuscript in whole, or in part may grant by the Department of Natural Science and or the School of Graduate Studies of Jimma University. In all other instances, however, permission should obtain from the author.

Name: **Shiferaw Diriba Danno**

Signature: ________________________

Place: Jimma University, Jimma

Date of submission: ______________

BIOGRAPHICAL SKETCH

The author, Shiferaw Diriba, was born on 10 June 1982 in Botor Tollay District, Jimma Zone of Oromia National Regional State. He attended his elementary education (grade 1-6) at Katta Elementary School from 1996-1997, grade 7 and 8 at Wayyu Wadessa secondary school from 1998-1999, grade 9 and 10 at Limmu Genet high school from 2000-2001. Mr. Shiferaw Diriba has received Diploma in Natural Resources Management from Kombolcha ATVET College in October 2004 and BSc in Natural Resources Management from Jimma University in June 2013. Mr. Shiferaw Diriba had worked for Limmu Kossa and Chora Botor District Agricultural office in Jimma Zone, Southwestern Ethiopia as an expert for six years.

ACKNOWLEDGEMENTS

I am indebted to various individuals and institutions whose contribution made the completion of this work possible. First, I would like to express my most sincere appreciation to my Advisors Prof. Dr. Oliver Hensel, and Mr. Chemeda Abdeta for their guidance and in puts from proposal write up to the final stage. Furthermore, I would like to extend my words of appreciation to Mr. Zerihun Kebebew for his fruitful comments and suggestion throughout my study and for their promotion. In addition, I would like to thank Dr. Debela Hunde for the coordination and facilitation. I would like to thanks Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) and Reduction of Loss and Adding Value (RELOAD) project for their financial and material support during my study. Special thanks for Chora Boter District Administrative Office and Agriculture and Rural Development Office who was gave me these chances to pursue my study. I cannot forget to thank Kasim Fite Boka and all other well-wishers who encouraged me in morally and financially to make my study a successful. To all who contributed in one way or another, my prayer to the Almighty God is that He may immensely bless you. Amen! Above all, I thank God for life, good health and success before and during the study.

ABBREVIATIONS

ACDI/VOCA	Agricultural Cooperative Development International
ANOVA	Analysis of variances
ATVET	Agricultural Technical Vocational Education Training
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food Agricultural origination
GCMC	Global circulation models
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
MOA	Ministry of agriculture
OECD	Economic Importance of Agriculture for Sustainable Development
RATES	Regional Agricultural Trade Expansion Support Program
UNFCC	United states Framework Convention on Climate change
USDA	United States Department of Agriculture Volunteers in Overseas Cooperative Assistance
WB	World Bank

TABLE OF CONTENTS

Contents Page

TABLE OF CONTENTS *(Contented)*

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

*Maize is the staple food crops in southwestern part of Ethiopia. Proper understanding of the farming systems and characterization across different agro-ecological zones was not studied which contribute to increase production and productivity. In addition, understanding environmental factors suitability for fungal growth can help different actors (farmers and traders) to setup management practices for intervention to reduce post-harvest loss and increase food security. Therefore, the study looked into the farming systems characteristics practiced by farmers and identify suitable temperature and relative humidity in stored maize for fungal pathogens growth in lowland, midland and highland agro-ecological settings considering maize supply chain in Jimma zone, southwest Ethiopia. Farming system characterization data and information were collected from 294 respondents (52 in lowland, 140 in midland, and 102 in highland) through household survey, interview and personal observation. Weather variables (temperature and relative humidity) data of inside farmers traditional storage structure ('gombisa') and ambient condition were recorded using data loggers (Testo 174 H, testo AG, Germany) from aforementioned agro-ecological settings. The survey result revealed that, mostly land of the study area allocated for cultivation as 53% in lowland, (63%) in midland and (70%) in highland compared to uncultivated and forestland in respective agro-ecology considered for current study. The kruskal-wallis result showed that there was a statistically highly significant (*p*< 0.001) difference among lowland, midland and highland agro-ecology in land use. In the study area 15 different crops produced, of this maize; teff and sorghum were the most common and dominate food crops. The result also revealed that, study area characterized by cereal based farming systems and majority of farming practices described by mono and mixed cropping system. There were highly significance (p<.001) difference among lowland, midland and highland agro-ecology in farming systems practices of different crops. It was also observed that, there were practices of managing trees in and around farmland. Moisture content of maize during maize harvesting and loading stage was not safe for long term-storage in all agro-ecological settings and storage materials except traders' storage in low land agro-ecology. Stored maize grains reduce its moisture as storage time increased to 60 days. However, moisture content fluctuate and sometimes increases above safe storage level due to exposure of grain to different ambient temperature and relative humidity and less protection of storage structures from ambient condition. Consequently, it exposes the stored maize grains for mycotoxin-producing fungal growth. High moisture content generally favors the development of storage fungi and low moisture content make the grain unfit for consumption. Monitoring of both temperature and relative humidity showed, all storage types and structures were favorable for fungi (Aspergillus, fusarium, and Pencillium species) growth. Pearson's correlation coefficient analysis result revealed that there were highly significant relationship of inside store and outside temperature, and relative humidity of maize grain stored under farmers' traditional storage, which has a considerable adverse effect on stored maize grain. Nevertheless, there was a non-significant relationship was observed with maize grain stored under collectors and wholesalers' storage systems. Farming systems in the study area are not homogeneity, mapping and clustering are very important to intervene in adoption of new technology. Furthermore, storage structures and practices in the study areas are not conditioned to reduce maize post-harvest loss that contribute to food security and there is a need to improve storage structures (especially farmers traditional storage systems) to reduce both quantity and quality losses.*

Key words: Farming Systems Characteristics, Storage Temperature and Relative Humidity

1. INTRODUCTION

1.1. Background

Maize is one of the most important food crops worldwide. It has the highest average yield per hectare and it grown in most parts of the world over a wide range of environmental conditions. Maize is generally less suited to semi-arid or equatorial climates, although drought-tolerant cultivars adapted to semi-arid conditions are now available (Brink and belay, 2006). It is one of the most important cereals cultivated in Ethiopia. It ranks second after teff in area coverage and first in total production (CSA, 2012). This crops and many of others has major role to ensure food security of the world. However, because of varies factor (like low production and productivity due to luck of new technology) it becoming difficult to meet the food requirement of the population, (UNDP, 2013). Due to this, certain regions will have trouble in natural resources (forest areas) in achieving higher food production, (Alemayehu *et.al.* 2012).

The agricultural sector and farming systems contribution to increase production and productivity in Ethiopia have major roles in ensuring food security, (Abera, 2011 and Gosh, 2005). A farming system; defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. The functioning of any individual farm system is strongly influenced by the external rural environment, policies, institutions, markets, and information linkages (Brinkman, *et.al.,* and Dixon *et.al.,* 2001). Each individual farm has its own specific characteristics arising from variations in resource endowments and family circumstances. The household, its resources, and the resource flows and interactions at this individual farm level are together referring to as a farm system (Dillon, 1978; Shaner and Norman, 1982). Farmers typically view their farms, whether small subsistence units or large corporations, as systems in their own right (Mellor, 2000). There is a typical farm system, drawn by farmers that illustrate the structural complexity and interrelationships between various components of a smallholder. The resource endowment of any particular farm depends, inter alia, on population density, the distribution of resources among households and the effectiveness of institutions in determining access to resources. Regardless of their size, individual farm systems organized to produce food and to meet other household goals through the management of available resources whether owned rented or jointly managed within the existing social, economic and institutional environment. From that resources; land, climate as well as human, social and financial capital are the one can listed (Mellor, 2000; Datt and Ravallion, 1998).

The contribution of each farming system to the national production of major crops and the degree of specialization is important. The share of each household type in the farming system in combination with their production orientation allows analyzing ability to adjust to, opportunities deriving from, and vulnerabilities to changing production conditions (Ghosh and Kuri, 2005). Therefore, farming system characterizing is important for Problems related to low production and productivity, which contributes in managing and conserving natural resources of the area. Using available technology formulates policy and manages farms without knowing farming system is also difficult. Socio-cultural pattern of human settlements has induced many different farming systems, each with its own agricultural land use rationale and organization. Farming system characterizing in line with adoption of new technologies in agriculture is of central interest to both academicians and policy makers, since it directly related to the efficiency of an agricultural research and extension system (Bozeman, 2000). Unfortunately, there are numerous examples of technologies with great potential that have not accepted by farmers, especially the smallholders of the developing countries. Quite often, these technologies do not fit well into heterogeneous smallholder systems, which need specific technological solutions. Such inherent variability often influences farmers' response to various technologies that aim at improving farm productivity and natural resource management (Lal *et.al*., 2001; Emtage and Suh, 2005). Farming has diversified greatly over recent years (Ghosh and Kuri 2005) and technological intervention with appropriate technology has become critically challenging to the extension system. That is why characterization of farming systems is a pragmatic starting point for facilitating appropriate technology in this region.

The study of farm typology is of practical interest for precise and effective technological interventions. Farm typology study recognizes that farmers are not a monolithic group and face differential constraints in their farming decisions depending on the resources available to them and their lifestyle (Soule, 2001). Ellis (1993) observes those small farmers always and everywhere typified by internal variations along many lines. Although every farm and farmer is unique in nature, that can be clustered into roughly homogeneous groups. Developing a typology constitutes an essential step in any realistic evaluation of constraints and opportunities that farmers face and helps forwarding appropriate technological solutions, policy interventions

(Ganpat and Bekele, 2001; Timothy, 1994; Vanclay, 2005), and comprehensive environmental assessment (Andersen *et.al.*, 2009). Moreover, typology studies are of paramount importance for understanding the factors that explain the adoption and/or rejection of new technologies (Mahapatra and Mitchell, 2001). The heterogeneity of farming systems is created by a host of biophysical (e.g. climate, soil fertility, slope etc.) and socio-economic (e.g. preferences, prices, production objectives etc.) factors (Ojiem *et.al.*, 2006). Most of the farm typology study has focused on socio-economic and agro-ecological factors for classification of farms. Economic factors have less used, especially in small-scale studies of classifying farms (USDA and ERS, 2000; Briggeman *et.al.*, 2007; Andersen, 2009).

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate change affects agriculture in a number of ways (including through changes in average temperature, rainfall, and climate extremes (e.g., heat waves)), changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods; and changes in sea level (UNFCC, 2014). In tropical and subtropical countries, a large proportion of the grain (such as maize) is harvested and stored under hot and humid conditions, and most farmers lack proper knowledge, equipment and methods of drying grains (Weinberg *et.al.*, 2008). Subsequently, the maize is stored while still relatively moist and warm; both warm and high moisture contents can result in rapid deterioration of the grains and promote the growth of microorganisms (e.g. fungi and bacteria) and insects in the grains (Ekechukwua and Norton, 1999). Maize, like other stored products is hygroscopic in nature and tends to absorb or release moisture. Even if properly dried after harvest, exposure to moist and humid conditions during storage will cause the grain to absorb water from the surroundings (Devereau *et.al.*, 2002), leading to increase maize moisture contents, which result in enhanced deterioration. To maintain high quality maize during storage, maize should have been protected from weather (including relative humidity and temperature), growth of microorganisms, and insects (Oyekale *et.al*, 2012). According to Campbell *et.al.*, (2004), the current estimates of the cost of grain loss due to insect and microorganism damage of grain stored in developing countries each year ranged from $500 million to $1 billion, Tuite and Foster, (1979) also reported that insects in grain enhance mold development because they increase moisture content and temperature. Major fungi types associated with Maize grain storage are *Aspergillus flavus, Fusarium species, and pencillium***.** Fungi are the second important cause of deterioration and loss of Maize next to insects and could cause about 50 to

80% of damage on farmers' Maize, during storage, if conditions are favorable for their development (Ali, *et.al.,* 2007).

A survey conducted in three major maize grain produced areas of Ethiopia indicated that the majority of farmers (93.3%) use traditional storage containers that expose their stored grains to attack by storage pests and/or other factors. The average actual loss per household was about 12 percent of the average total grain produce (Abebe and Bekele, 2006). Grain storage containers being used by majority of farmers in Jimma zone (more than 97%) are traditional ones that couldn't protect the stored grain from deterioration which is faced to different factors (Kemeru, 2007). Food losses during storage are the result of biological, chemical or physical damage. Damage of stored food grains is very serious problem in our country and throughout the globe (Echezona and Iloba, 2005). One of the damage is environmental factors such as humidity & temperature (Echezona and Iloba, 2005). Environmental factors include internal factors like temperature, moisture content and relative humidity and external factors like optimum temperature and relative humidity affects the maize stored. As temperature increases, grain will lose moisture to the surrounding air, thereby increasing the relative humidity (Devereau *et.al.,* 2002), that changing temperature and relative humidity promotes molds growth (Rehman *et.al.,* 2002 and Samuel *et.al.,* 2011). Moisture content and temperature are the two key environmental factors that influence growth of molds and fungi (Alborch *et.al., 2011*). Moisture content plays a significant role in the storage of grain when grain has more moisture, it heats up and could have mold spoilage (Brewbaker, 2003).

Based on these facts, even though many places have potential for crops production of different crops, there were no full information which describes farming system characteristics, which used for farmer, government and institution by giving information so as to identify production priority, to conduct research, formulate policy, set management practices and to intervene.

On the other hand, there was also no full information that describes the exact cause of climate (temperature and relative humidity) deterioration of grains stored in these traditional storages in Jimma zone, southwestern part of Ethiopia that could serve as basis to take corrective measures. Therefore, this paper would give information on intended topic.

Significance of the study

While knowing the impacts of environmental factors in maize grain stored has advantage to prevent problem like decline of maize grain in quality and quantity, to stored maize grain for long time. It is important knowing which duration of storage time would favorable for fungal pathogens wide spread in the study area and important to prevent from causes, which threaten grain stored. So, this research enables us knowing this climate factors which affects maize grain in storage so as to store maize for long times and helps to improve the livelihood of the community as well as quality and quantity of the Maize. The outcome of farming system characterization has advantage by giving base line information, which uses for farmers, policy makers and planners in design and implementation of good crop farming management and for conducting research purposes for better crop production and productivity.

1.2. Objectives

The general objectives of the study was to characterize farming system and identify effects of temperature and relative's humidity for maize grain stored in storage structure at selected districts of Jimma zone.

The specific objectives are

- To assess the types of farming system in the study
- To identify favorability of temperature and relative humidity for maize grain stored under different storage structure conditions.
- To examine the extent of climate factor for fungal pathogens attack in stored maize grain

Research questions: The research questions were

- What are the major agricultural farming systems of the study area?
- What are the temperature and relative humidity's of maize grain stored under different storage structure indicates for fungal pathogen favorability to flourish?

2. LITERATURE REVIEW

2.1. Agricultural Farming System and Their Characteristics

Farming system is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well-defined practices in response to the physical, biological and socio-economic environment and in accordance with the household goals preferences and resources. These factors combine to influence the output and production methods. More commonalities will be founds within system than between systems. Farming system belongs to a larger system, (FAO 2000). The heterogeneity of farming systems is created by a host of biophysical (e.g. climate, soil fertility, slope etc.) and socio-economic (e.g. preferences, prices, production objectives etc.) factors (Ojiem *et.al.*, 2006). Most of the farm typology study has focused on socio-economic and agro-ecological factors for classification of farms. Economic factors have less used, especially in small-scale studies, for classifying farms (USDA and ERS, 2000; Briggeman *et.al.*, 2007; Andersen 2009). Characterization involves an understanding of the structural and functional relationships of current farming systems in specific geographical areas and an identification of the endogenous and exogenous constraints to achieving farmers' goals (FAO, 200).

Farmers typically view their farms, whether small subsistence units or large corporations, as systems in their own right (Mellor, 2000). There is a typical farm system, drawn by farmers that illustrate the structural complexity and interrelationships between various components of a smallholding. From that one is resources are land and climate as well as human, social and financial capital (Mellor, 2000, and Datt & Ravallion, 1998). Farming system typologies dictated by climate, production goals and culture with a farming system described as a unit consisting of a human group (usually a household) and the resources it manages in its environment, involving the direct production of plant and/or animal products (Scherr, 1997b, 1999; FAO, 1990). The farming system describes what a group of farmers operating under certain common conditions is currently doing. The system focuses on farm-household and rural community systems and their interactions with physical, socio-cultural and political environments forming the backbone of these farming systems (Obanyi *et.al.*, 2012).

2.2. Agro-Ecology and Their Classification of Ethiopia

There is no single way to define agro-ecology, but the concept unifies different groups of scientists, practitioners in the food system, and social movements. According to Altieri, (1995), agro-ecology defined as the application of ecological systems to agriculture. Twenty years later, agro-ecology enlarged to the whole food system linking production with the food chain and consumers. Wezel *et.al.*, (2009) concluded that agro-ecology means a scientific discipline that questions the dominant agronomic model based on the intensive use of external inputs, the dominant ecological model that separates the protection of biodiversity from the production of food. As such, it proposes an additional new role for farmers as stewards of the landscape and biodiversity. According to Menale *et.al.*, (2009) agro-ecology shapes the performance of agriculture in Ethiopia. This implies that the profitability of adopting sustainable agricultural practices will depend on the distribution of rainfall that affected by agro-ecology and thus this should play a role when formulating policies that promote adoption of productivity-enhancing technologies, such as fertilizers and reduced tillage. Agro-ecological zonation is doing in different ways in different countries.

According to Dereje *et.al.*, (2011) in Ethiopia two classification systems are known that include the traditional agro- ecological zones and the elaborated agro-ecological zones developed by MOA and EIAR. The traditional zones include *Bereha, Kolla, Woina Dega, Dega*, *Wurch* and *Kur* where many kinds of crops grown in each of these ecological zones. A major attempt to carry out an agro-ecological zonation for the country was take up by Mengistu Negash *et.al.*, (1989). Principal information for characterizing the major agro-ecological zones (MAZs) and sub-zones was the moisture regime, the thermal regime, and physio-pedomorphic regions of the country. All studies confirm the importance of altitudes above sea level as the primary denominator of agro-ecological zonation. In terms of Agro-ecology, Jimma Zone enjoys seven different types of climate conditions which include, Moist Dega (21.675 ha), Moist Kolla (73445.047 ha), Moist Weinadega (125216.83), Wet Dega (233401.823), Wet Kolla (99268.614), Wet Weina dega (1280822.049) and Wet Wurch (438.173). From here, one can easily observe that the larger part of the land lies under Wet Dega, Moist Weina dega and Wet Weina dega. Whereas Wet Kolla, Moist Kolla, Moist Dega and Wet Wurch in aggregate cover less than 25% of the total existing hectares of land of Jimma Zone. The total area of the zone is 1,812,614.217 ha (Table.1) (Ephrem, 2013).

Table 1. Annual rainfall distribution for Jimma zone

		Annual rainfall distribution		
No	Elevation	<900	900-1400	>1400
1	Wet alpine	Dry Alpine Wurch	Moist Alpine wurch	Wurch
2	3200-3700	Dry wurch	Moist wurch	Wet wurch
3	2300-3200	Moist Dega	Moist Dega	Wet dega
4	1500-2300	Moist Weina dega	Moist Weina dega	Wet Weina dega
5	500-1500	Moist kola	Moist Kolla	Wet kollaa
6	<500	Dry Bereha	Moist Bereha	None

Ephrem T., 2013; Annual Rainfall Distribution for Jimma Zone moist Weina dega

2.3. Crops Production and Agro Ecology of Ethiopia

According to Dereje *et.al.*, (2011) different crops are adapting to the different agro-ecologies; for example, Teff is a cool weather crop grown predominantly in the highlands at optimum altitude range from 1800 to 2200 masl while maize and sorghum are common warm weather cereal crops. They are cultivated mostly at lower altitudes along the country's western, southwestern, and eastern peripheries. Now days they grown between elevations of l500 and 2200 masl and require large amounts of rainfall for good harvests. Currently, maize is widely grown in most parts of the world over a wide range of environmental conditions ranging between 50^o latitude north and south of the equator. In the tropics, maize does best with 600-900 mm well-distributed rainfall during the growing season (Brink and Belay, 2006). The most suitable soil for maize is one with a good effective depth, favorable morphological properties, good internal drainage, and an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favorable specifically for maize production. Although large-scale maize production takes place on soils with a clay content of less than 10% (sandy soils) or in excess of 30% (clay and clay loam soils), the textural classes between 10 and 30% (clay) have air and moisture regimes that are optimal for healthy maize production and productivity. The maize productivity gap between stressed and high potential areas is not only an issue of technology but also differences in climatic factors. Non-availability of suitable maize varieties is also responsible for such a significant yield reduction. Unavailability of improved infrastructure and maize grain marketing represents major limiting factors for maize production. Wise utilization and conservation of natural resources will also have a significant impact on maize grain production (Mosisa *et.al.*, 2001).

2.4. Agricultural Resources and Farming Community

Land is by far the most important resource of the sample farming communities. Allocation of this scarce resource apparently indicates the importance farmers attach to the different crops they are growing. Accordingly, a look into the proportion of area allocated to different types of maize vs. other types of crop verifies the importance of maize at household level (Girma and Kassie, 2012). The art of purposeful of crop and livestock to men and in varying degrees, the preparation of this product for mean’s use and their disposal for Small farmers are the key groups requiring attention in agricultural and rural development. Increasing their productivity and incomes can make a major contribution to reduce hunger and poverty (WDI, 2007). Small-scale peasant households produce crops and livestock mainly for their family and they are profit maximize as firms. Their lack of access to decent inputs, including good quality land smart technologies (including), and good quality seeds, lack of access to capital markets, credit and information about both growing conditions often marginalize these small-scale producers and markets are areas that marginalize, small-scale producers (Murphy, 2012).

2.5. Impacts of Climate Change on Agricultures

Throughout the 21stcentury, the global climate forecasted to be continuing changing. Global circulation models (GCMs) higher mean temperature and changing in rainfall regimes show that there will be radical shift in land use and crop suitability, in addition to increasing vulnerability to climate change variability. Agricultural productivity, farm income and food security will be affected by climate change and variability as well as climate extreme events (Peter *et.al.*, 2011). There is significant concern about the impact of climate change and its variability on agricultural production and problem of food security highlighted in the list of human activities and anthropogenic interference on Earth’s climate (Watson *et.al.*, 2000;

IPCC, 2001). According to the IPCC, (2007), mainly the tropics and sub tropics particularly sub-Saharan Africa's agriculture adversely impacted by climate change and there is limitation on it i.e. the approach focuses mainly on physical damages, such as yield and income. For example, a study on the effect of climate change on yield can show the decrease in yield due to simulated climatic variables, such as increased temperature or reduced precipitation (Deresse *et.al.*, 2008). Generally, the biophysical approach focuses on sensitivity (change in yield, income, health) to climate change and oversights much of the adaptive capacity of individuals or social groups, which is more described by their internal characteristics or by the style of entitlements (Derresa *et.al*., 2010).

2.6. Environmental Factors for Stored Grain Crops

Moisture content and temperature are the two key environmental factors that influence growth of molds and fungi (Alborch *et.al., 2011*). Temperature and moisture content of the cereal grains are the two key features affecting the storage of the grain (Lawrence and Maier, 2010). Stored grains considered an ecological system. Jian and Jayas (2012) described it as an approach by which grain integrated with factors such as relative humidity and temperature to promote protection of grain and environments to deliver good quality grain at the end of storage time. Practice of grain storage has direct effects on quality of stored grain. According to Nukenine, (2010), "storage is a way or process by which agricultural products or produce are kept for future use". In maize storage ecosystems, the most important factors that influence molds and insect's infestation are water activity, temperature and air (Montross, *et.al.*, 1999). In addition, grain temperature and moisture content affects grain quality in storage and promotes growth and development of molds, insects, mites and dry matter losses (Maier *et.al.,* 1996).

2.6.1. Temperature and moisture content factors on grain stored

Maize grain generally harvested with moisture content of around 18 % to 20 % and then dried. If inadequately dried the conditions are favorable for molds and fungi to grow, which can result in a significant decrease in grain quality and quantity (Marín *et.al*., 1998). Rees, (2004), report that fungal growth in stored grain in the tropical countries is mainly associated with increases in grain moisture contents, and fluctuation in temperatures, resulting in unsafe storage of high-moisture grain and moisture migration and condensation. Furthermore, a study conducted by Reed *et.al*., (2007) on the effect of moisture contents and temperature on storage molds, found that the higher the initial moisture contents the greater the infection of maize kernels. According to Miller (1995), the growth and development of storage fungi in grain are governed by three main factors, crop (nutrients), physical (temperature, moisture) and biotic (insects, interference competition) factors. Biological and biochemical activities occur only when moisture is present. Hence, for safe storage of grain, both the moisture content of the grain and that of the surrounding air should reduce and monitored (Jayas and White, 2003). Maize grains, like other stored products, are hygroscopic materials (i.e. they absorb and release water). They consist of a constant amount of dry matter but water content will vary (Devereau *et.al.*, 2002). Moisture content plays a significant role in the storage of grain; when grain has more moisture, it heats up and can have mold spoilage (Brewbaker, 2003). As a general expression, the higher the moisture content, the more susceptible the maize grain is to mold and insect deterioration. Allowable storage time is cumulative term and functions of temperature and Maize moisture contents; maize at 20 % moisture content and 60 °F has an allowable storage time of 29 days. If after five days, the maize dried to 18 %, the allowable storage time at 18 % and 60 °F will be 46days (Hellevang, 2005; and Bern *et.al*, 2013).

2.6.2. Relative humidity and moisture content in stored grain

Relative humidity can described as the amount of water vapor that is contained in the air as a proportion of the amount of water vapor required to saturate the air at the same temperature (Lawrence, 2005). Several studies have been conducted to examine the relationship between temperature and relative humidity (RH) in grain storage in the tropics, and results have revealed a direct relationship between them, that is, as temperature increases, grain will lose moisture to the surrounding air, thereby increasing the relative humidity (Devereau *et.al.*, 2002). A findings of Mirna, indicated that; Analysis of variance did not show significant differences in moisture content changes in maize grain concerning different values of relative humidity (55%, 73%, 80% and 98%) and at the temperatures of 0°C and 20°C during 34 days storing period. Results of the grain moisture maize at 0 °C during 34 days' storage at 0°C and relative humidity of 55%, moisture in maize grain decreased 0.2%, while at the relative humidity of 73%, 80% and 98% it increased, 0.4%, 1% and 1.5%. Results of the grain moisture in maize at 20°C at the temperature of 20°C and relative humidity of 55%, moisture in maize grain decreased 1.5% and at the relative humidity of 73%, 80% and 98% increased, 0.2%, 0.9% and 1.7% (Mirna *et.al.*, 2006).

2.6.3. Interaction of temperature and relatives humidity in grain stored

Several studies have been conducted to examine the relationship between temperature and relative humidity (RH) in grain storage in the tropics, and results have revealed a direct relationship between them, that is, as temperature increases, grain will lose moisture to the surrounding air, thereby increasing the relative humidity (Devereau *et.al.,* 2002). It has observed that in most cereal grains, every 10 °C rise in temperature causes an increase of about 3 % in relative humidity (ACDI/VOCA, 2003). Shah *et.al.*, (2002), explained that a change of temperature and relative humidity promotes molds growth.

Rehman *et.al*, (2002) and Samuel *et.al,* (2011), explained that even maize after dried and harvested in tropical countries retained a certain amount of moisture when exposed to air and exchanges of moisture between the maize grains and surrounding occur until the equilibrium reached. According to Samuel *et.al,*(2011) and (Yakubu, 2009) beside this, fluctuation of temperature and relative humidity in tropical countries accelerates rapid multiplication of molds and insects, which facilitate further spoilage of grain.

2.6.4. Deteriorations of the grain and environmental factors

Mold and fungal species can develop on grains, in the field as well as in storage (Table 1). Contamination of maize grain with mold and fungi regarded as one of the most serious safety problems in the tropical countries and throughout the world (Kaaya and Kyamuhangire, 2006). Toxigenic fungi invading maize divided into two distinct groups, field fungi and storage fungi (Barney *et.al*, 1995). Field fungi invade maize and produce toxins before harvest or before the grains are threshed, and can develop under high relative humidity of over 80 %, with moisture content of 22 % to 33 % and wide range of temperature (10 ± 35 °C) (Williams and Macdonald, 1983; Montross *et.al.*, 1999). These usually die out in storage, but some can live under storage conditions (Sanchis *et.al.*, 1982), that can cause significant damage, reducing the yield and quality, especially in warm humid climates (Moturi, 2008). Conversely, storage fungi invade grain primarily during storage and require moisture content in equilibrium with relative humidity of 70 % to 90 %. In both circumstances, fungi originated from the field. Storage molds replace field molds that invade/ contaminate the maize before harvest (Reed *et.al.*, 2007).

There are several key fungal species associated with stored grains, including *Fusarium spp., Pencillium spp., Rhizopus spp., Aspergillus species* and *Tilletia species*. (Barney *et.al.,* 1995). Infection of maize grain by storage fungus results in discoloration, dry matter loss, chemical and nutritional changes and overall reduction of maize grain quality (Chuck *et.al.*, 2012). It has been reported by Fandohan *et.al.*, (2003) that storage fungi contributes to loss of more than 50 % of maize grain in tropical countries, and ranks second after insects as the major cause of deterioration and loss of maize. According to Williams and McDonald (1983), when storage molds invade maize grain they cause rot, kernel discoloration, loss of viability, mycotoxin contamination, and subsequent seedling diseases. It revealed by Sone (2001), that broken maize and foreign materials promote development of storage molds, because fungi more easily penetrate broken kernels than intact kernels. Similarly Dharmaputra *et.al.,* (1994) reported that mechanical damages during or after harvesting on maize grains can provide entry points to fungal spores. Likewise, Fandohan *et.al.,* (2006) reported that increases in grain damage and cracking create an opportunity for fungi to grow and penetrate the maize grain. Mold and fungal species can develop on grains, in the field as well as in storage (Table, 2)contamination of maize grain with mold and fungi is regarded as one of the most serious safety problems in the tropical countries and throughout the world (Kaaya and Kyamuhangire, 2006).

Table 2. Conditions for growth of common storage mold on cereals and grain at 25°C to2 7°C (Montross *et.al*., 1999)

Moisture content ($^{o}{}_{C}$).	**Relative humidity**	**(%)**
Aspergillus halophilieus	12-14	68
A. restrictus	13-15	70
A.glaucus	13-15	73
A. candidus A. ochraeus	14-16	80
A.flavus, parssiticus	15-18	82
Pencillium spp	15-18	80-90

Sources, Montross *et.al.,* 1999. Conditions for growth of common storage mold on cereals and grain at 25°C to2 7°C.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

This research was conducted in Jimma Zone, located in Oromia National Regional State in southwestern Ethiopia. Agriculture is the main economic activity in the study area, where Maize, teff and sorghum are the major crops grown. The zone has an elevation ranging from 880 to 3360 meters above sea level (masl). Jimma zone area experiences annual average rainfall of 1000 mm for 8 to 10 months. The main rainy season extends from May to September and the small rainy season takes place in February, March and April. The temperature of Jimma zone varies from 8-28°C. The mean annual temperature is 20°C (Haile and Tole Mariam 2008). The study area has an altitude range of 1000-1500 (lowlands), 1500-2500 (midland) and 2500-3360 masl (highlands), (FAO, 2009).

Based on the Census conducted by the CSA 2007 , this Zone has a total population of 2,486,155, an increase of 26.76% over the 1994 census, of whom 1,250,527 are men and 1,235,628 women; with an area of 15,568.58 square kilometers, Jimma has a population density of 159.69. While 137,668 or 11.31% are urban inhabitants, a further 858 or 0.03% are pastoralists. The total of 521,506 households were counted in this Zone, which results in an average of 4.77 persons to a household, and 500,374 housing units (CSA, 2014).

This research was conducted in three districts (Sokoru, Omo naddaa and Dedo) selected from lowland, midland and high land agro-ecology, respectively. Those districts represented among high Maize producers. Jimma town is found at about 345 km from Addis Ababa in South west and lies between 36° 10´ E and 7° 40´ N.

Sokoru was one of the study area district which represents low land agro-ecology and among the top maize producing districts of Jimma zone. The altitude of this district ranges from 1160 to 2940 meters above sea level. Based on figures published by the Central Statistical Agency in 2005, this district has an estimated total population of 157,552, of whom 79,305 were males and 78,247 were females; 19,676 or 12.49% of its population are urban dwellers, which is about the same as the Zone average of 12.3%. With an estimated area of 923.44 square kilometers, Sokoru has an estimated population density of 170.6

people per square kilometer, which is greater than the Zone average of 150.6 (CSA, 2005), (CSA, 2014).

Omo Nada was one of the study area district which represent Mid land agro-ecology and among the top Maize producing district of Jimma zone and has some potential of Maize producing site was selected. The altitude of this district ranges from 1000 to 3340 meters above sea level. Based on figures published by the Central Statistical Agency in 2005, this district has an estimated total population of 254,417, of whom 127,625 were men and 126,792 women; 12,958 or 5.09% of its population are urban dwellers, which is less than the Zone average of 12.3%. With an estimated area of 1,602.66 square kilometers, Omo Nada has an estimated population density of 158.7 people per square kilometer, which is greater than the Zone average of 150.6 CSA, (2005), (CSA, 2014).

Dedo was one of the study area district which represents high land agro-ecology and among the top maize producing district of Jimma zone and some potential Maize producing site was selected. The altitude of this district ranges from 880 to 2400 meters above sea level. Based on figures published by the Central Statistical Agency in 2005, this district has an estimated total population of 308,544, of whom 155,596 are men and 152,948 are women; 7,718 or 2.5% of its population are urban dwellers, which is less than the Zone average of 12.3%. With an estimated area of 1,571.72 square kilometers, Dedo has an estimated population density of 196.3 people per square kilometer, which is greater than the Zone average of 150.6, CSA (2005), (CSA, 2014).

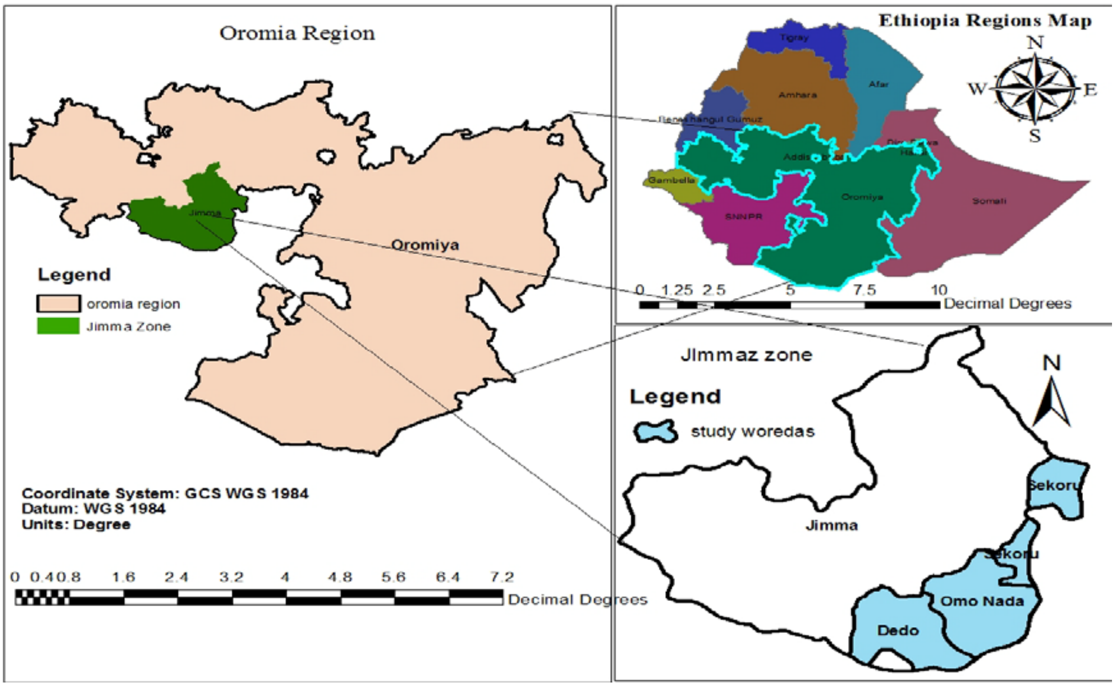


Figure 1: Map of the study area: Sokoru, Dedo and Omo Nadda

3.2. Sample respondents Selection

A three-stage sampling (first selects PA, second PA zone and third sample respondents from each PA zones) a technique was used to select the respondents from each study area. For the study, three districts (Sokoru, Omo nadda and Dedo) purposively selected based on different agro-ecology and agricultural activities. Jimma zone selected from South West of Ethiopia, based on Maize producing potential and minimum research reports in the area. From each districts, three *kebeles* (Peasant associations) were selected (Abalti, Andode and Walmara) from Sekoru district, (Nadda Chala, Gudeta Bula and Burka Hassandabo) from Omo nadda districts and (Mole, Offole and Warokolobo) from Dedo. Sample size and respondent selected using Cochran's sample size formula (Bartlett *et al*., 2001).

According to this: - $n = x^2 *(q)(q)/d^2$

$n' = n/1+n/N$ Where, n= sample size

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

N = the population size.

p = the population proportion (assumed to be 0.30 since this would provide the Maximum sample sizes).

q= 1-p, d^2 = the degree of accuracy expressed as a proportion ($\alpha = 0.05$).

Since the percentage of the sample size was preferably greater than 5%, Cochran's corrected sample size were calculated as n'= n/1+n/N. Accordingly, sampled sizes of the three districts of nine kebeles are 294 farmers were interviewed (Table3). Finally, all participants selected randomly to avoid biases during data collection.

Table 3. Sample size of the participant farmers across study area

No	Agro-ecology	Districts	PA	Total no. of HH	Total no. of sampled HH, using Cochran's sample size formula
1	Highland	Dedo	Mole	635	40
			Offole	546	34
			Warokolobo	456	28
2	Midland	Omo Nadda	Nadda Chala	876	55
			Gudeta Bula	698	44
			B/Hassandabo	653	41
3	Lowland	Sokoru	Abalti	127	8
			Andode	159	10
			Walmara	551	34
			Total	4701	294

3.3. Respondents Survey and Data Collection

The survey carried out to collect both primary and secondary data to generate reliable information on the intended topic. Secondary data collected from districts offices, Zonal office, published Journal articles, reports and other relevant documents. However, primary data were collected from selected households using semi-structured questionnaires using house-to-house survey. In order to collect reliable information for farming systems characters, pre-test of questionnaires made at afore mentioned districts and amendment made for final interview. Each questionnaire filled with selected participants across study area. Data collection held with different individual’s age ranging from the elder group of community to the officials, elders and youngsters in the field. During interview information regarding, socio-economic of the participants, demographic information, resources endowment, livestock assets of the household, major crops grown in the area and areal coverage of each crop was included. Characterizing of farming system designed to carry out in potential maize based producing areas of selected districts of Jimma zone in southwestern Ethiopia.

3.4. Weather Variables For Mycological (The Study of Fungi) Study

Agro-ecologies factors at three levels low land , middle and high land, from low land Sokoru districts Abalti PAs and Sokoru town , from intermediate O/Nadda districts Nadda Chala PAs and Nadda town and from high land, Dedo district in Mole PAs and Sheki town the research was employed both in *gombisa a*(traditional maize storage) and sacks storage(Table 3). Traditional maize storage containers two levels *gombisa* and sacks used. The study was conduct for six months, which in 2014/2015 harvesting season and the study area selected purposively. Maize variety, Bako Hybrid(BH-660) which was produced by more than ninety percent of the farmers in Jimma zone were used for the study purposes during 2014/2015 production season. Farmers in the study area used traditional storage *gombisa* to store their Maize in cobs. For mycological study, uniformity *gombisa* were built in three agro-ecology (lowland, midland and highland) of Sokoru, Omo Nadda and Dedo districts, respectively. The storage were built with similar shape(conical shape), size (circumstances 541 cm), roof Length(197cm), root length(250cm), root width(203cm) and similar construction materials(Bamboo) and grass thatched roof in all agro-ecology. The storage was rests on leveled area put it on six stone piles(Fig.2).

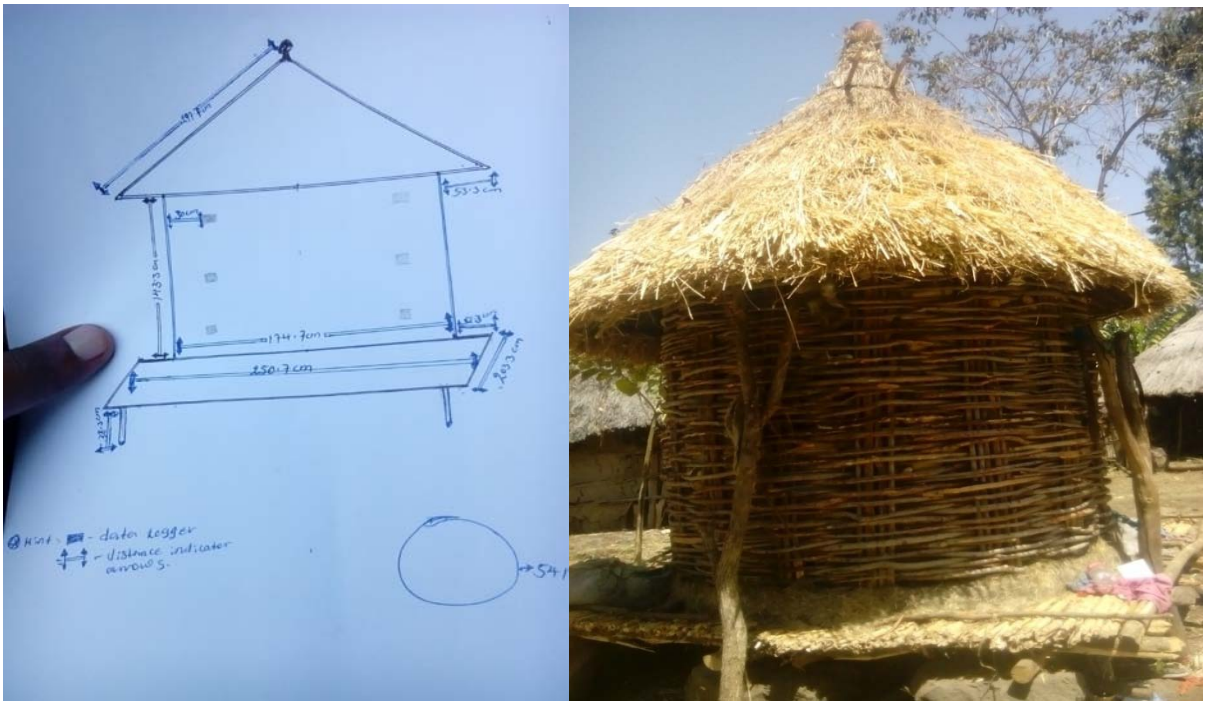


Figure 2. Storage structure of the study area

While polypropylene sacks used for storage maize grains by collectors and wholesalers in town. Sacks are a type of storage container, which used for storage especially by traders (collectors and wholesalers) in the study area and made by interwoven synthetic fiber similar to plastic. It considered as a low cost indoor storage, which mostly wholesaler and collectors used to store as well as to transport. It is one of non-airtight storage container. It can hold up to 100 kg of shelled maize. Sacks was stacked horizontally one on top of the other close to the wall inside the storage.

Using portable digital USB Data Logger by putting data logger in *gombisa* at bottom, middle and upper portion of the storage in two sides *i.e.* side-by-side, data logger placed 30cm away from the storage wall. In sacks storage data logger kept at the center of bottom, middle and upper around collector and whole seller in three agro-ecology. However, one data logger kept outside of the storage to measures ambient condition of the environment around *gombisa* of farmers and storage house of collectors three agro-ecology.

Digital USB Data Logger and174H Testo data loggers used to record temperature, relative humidity and ambient condition of the environment inside the store and outside of the store. At each storage condition and agro-ecology, totally 37 data logger were kept inside and outside of the storage to record ambient condition of environment, temperature and relative humidity. Both temperature and relative humidity recorded with interval of 30 minutes starting from loading stage to six months of storages (from 12-28-2014 up to 06-25-2015 of 2014/2015) harvesting season. Optimum temperature measured around *gombisa* of farmers and storage house of collectors at threes agro-ecology. Moisture content was recorded using Calibrate moisture taster starting at storing stage and continued with two months interval till six months of storage using calibrate moisture taster in all agro-ecology and both *gombisa* and sacks. Moisture content of the stored maize was record by taking from bottom, middle, and upper of the storage of all agro-ecology and from both *gombisa* and sacks storage.

Table 4. Description of farmers, collector and whole sellers' storage study area

Actors	Districts	PA	Altitude (masl)	Latitude/N	Longitude/E
Farmer	Sokoru	Abalti	1676	08º17-4263º	037º57-0782º
	O/Nadda	Nadda Chala	1886	07º36-520º	037º12-150º
	Dedo	Mole	2054	07º28-533º	036º59-492º
Collector	Sokoru	Sokoru Town	1910	07º55-419º	037º25-391º
	O/Nadda	Nadda Town	1823	07º38-142º	037º15-113º
	Dedo	Sheki	2234	07º30-446º	036º52-871º
Wholesaler	Jimma	Jimma Town	1734	07º46-675º	036º49-865º

3.6. Data Processing and Analysis

This study was carried out using Statistical analysis to perform response variables collected over demographic and socio-economic characteristics. Family labor for agricultural activities, farming systems characteristics and distribution of-farmland and trees were analyzed using chi-square, percentages, descriptive statics, and means of SPSS (Statistical Package for the IBM) Version 20. Analyses of variance (*Kruskal-Wallis*) run on land holding size, use type and farmland allocation among different crops R-software runs on temperature and relative humidity of storage structure and across agro-ecology to show the difference. Minitab

Person’s correlation runs for temperature and relative humidity comparing inside the maize store with the ambient condition for maize stored under different actor storage condition. Descriptive statistics and means also used for organizing and presenting the data of moisture, temperature, relative humidity, optimum temperatures and optimum relative humidity to compare data and presenting the results.

4. RESULTS AND DISCUSSIONS

4.1. Farming Systems Characteristics of the Study Area

4.1.1. Respondent characteristics

Respondent characteristics showed that the largest proportion of the respondents were males. The result also shows that most of the respondents were between 36 to 55 years old. Agriculture is the mainstay of the livelihoods in lowland, midland and highland. The chi-square result showed that there are differences in demographic and socioeconomic characteristics in lowland, midland and highland ($P<0.05$), the implication is that the responses of the respondents are independent and do not influenced each other.

Education is an important a variable that increases an individual's ability to acquire, process, and use agricultural information to meet their wishes and increase their productivity and potential to improve their quality of life. The analysis showed that about 65% in lowland, 44% in midland and 29% in highland of the respondents had no formal education and were not able to read and write. The chi-square result showed that there are differences ($P<0.05$), in education status of the households in lowland, midland and highland. The average family size of the respondent was about seven (Table 5).

According to World Bank, (2012), the productive age ranges between 15 and 65 years old. This shows that the largest proportion of the respondents were in productive age categories. The findings are in agreement with the findings of Oumer, (2011) who reported that 60% of the households in Jimma Zone were in the age categories between 31 to 50 years old. In the study area, agriculture is the mainstay of the livelihoods. The findings are in agreement with the finding of OECD, (2010) who reported that agriculture has mainstay of livelihood in rural area. According to NBE and CSA, (2013) in Ethiopia, about 83.9 % of total population is lives in rural area and agriculture is main source of their livelihood, by providing employment for 80 % of the total labors force and contributes 42.7 % to Gross Domestic Product and 70 percent of foreign exchange earnings. The educational background finding of the study findings are similar with the findings of Belay, *et.al.*, (2012) who's reported that majority of the respondent in rural area of his study area were illiterate. However, the study findings are not in support of Solomon, (2008) who stated that the majority of present-day farmers had some formal education and high literacy among the respondents may enhance adoption of innovations that related to farming.

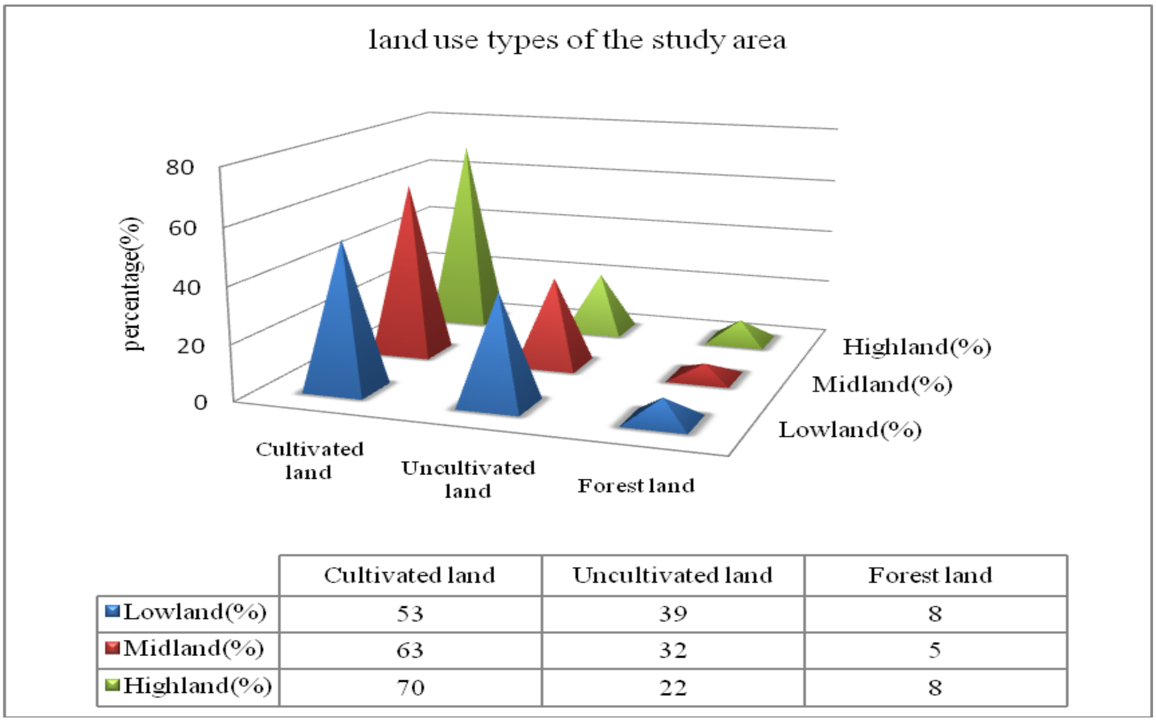
Table 5. Characteristics of the respondents

	Agro ecology		
	Low land (N=52)	Midland(N=140)	Highland(N=102)
Sex (%)			
Male	100	99.3	98.04
Female		0.7	1.96
Age (%)			
18-35	11.54	22.14	21.57
36-55	55.77	63.57	54.9
56-75	32.69	13.57	23.53
Religion (%)			
Orthodox	7.69		3.92
Muslims	92.31	99.29	95.1
Protestant		0.71	0.98
Marital status			
Single	11.54	4.29	1.96
Married	88.46	94.29	95.2
Widowed		1.43	1.96
Divorced			0.98
Education (%)			
Cannot read and Write	65.39	44.29	29.41
Can read and write	13.46	21.43	16.67
Grade 1 to 4	11.54	21.43	43.14
Grade 5 to 8	5.77	8.57	4.9
Grade 9 to 10	3.85	3.57	5.88
Family size per HH(no)	7	7	7
Main occupation (%)			
Agriculture	100	99.29	99.02
Petty Trading			0.98
Other		0.71	

4.1.2. Characteristics of the farming systems

4.1.2.1. Land use type of the study area

Assessment of land use result showed that cultivated, uncultivated and forestland were the three types of land use at household level in the three agro-ecology. From the three land use types, cultivated land account largest proportion in lowland, midland and highland agro-ecology (Figure3). The kruskal-wallis result showed that there was a statistically highly significant difference ($p< 0.001$) among lowland, midland and highland in terms of land use. The results indicated that responses of the respondent were independent variables and one does not influence the other. The findings are in agreement with the findings of existing literature, which indicates that larger proportion of land was allocated for cultivation than uncultivated and forestland (Oumer, 2011).



	Cultivated land	Uncultivated land	Forest land
🟦 Lowland(%)	53	39	8
🟥 Midland(%)	63	32	5
🟩 Highland(%)	70	22	8

Figure 3. Land use types of the study area

4.1.2.2. Land holding size of the respondent

The land holding size of the household varies in lowland, midland and highland. The results showed that mean are 3.5 ha in lowland, 3ha in midland and1.5ha in highland were recorded. The findings indicated that more land size allocated in lowland agro-ecology than midland and highland agro-ecology (Fig.4). The results of one way ANOVA in ranks indicated that, there was highly significant difference among lowland, midland and highland agro-ecology of land holding size.

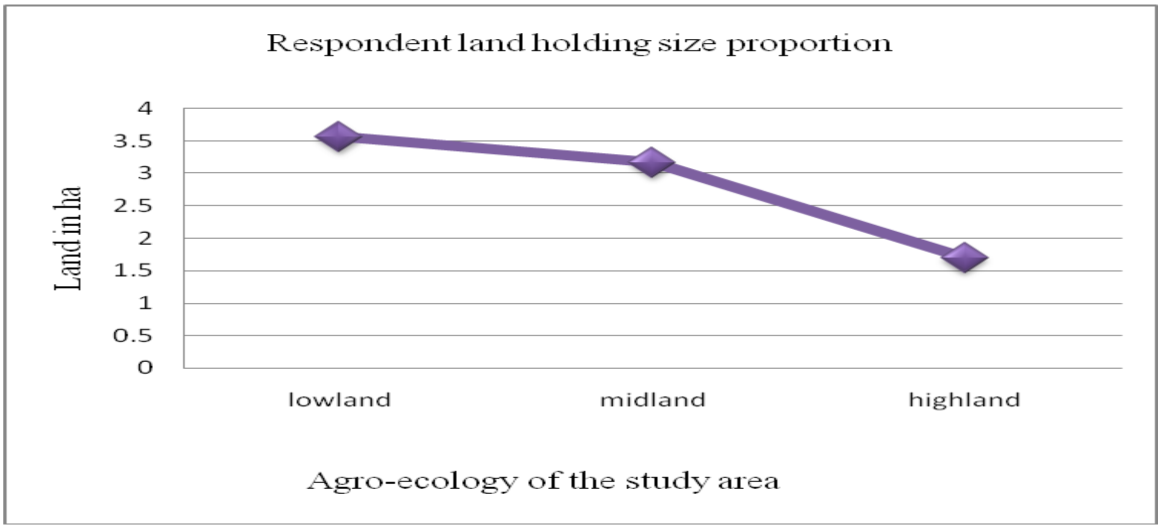


Figure 4. Mean Land holding size of the respondnets

4.1.2.3. Farm land allocation among different crops and farming systems

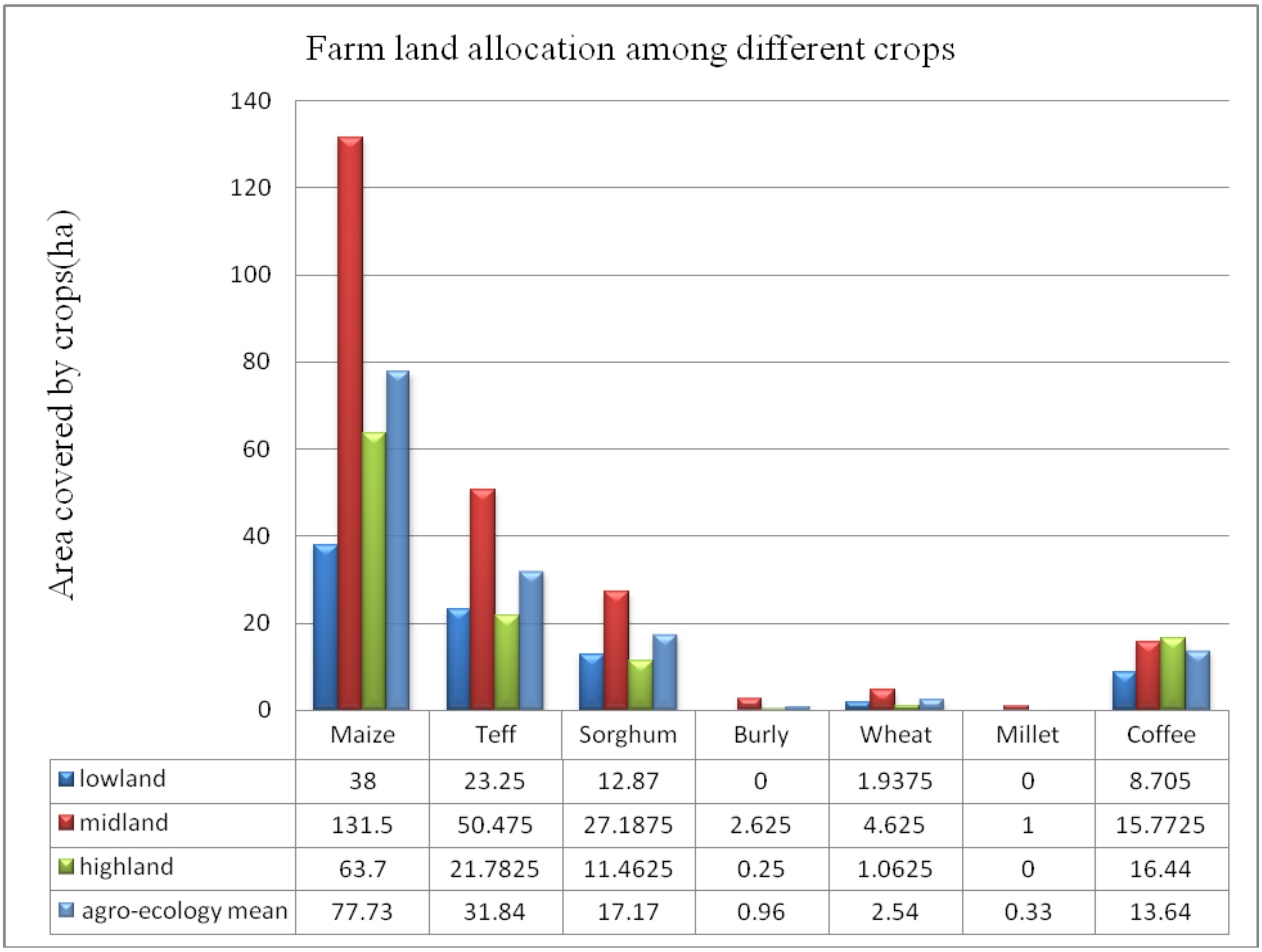
Annual and perennial crops were mainly cultivated at households' level in the threes agro-ecology. The results revealed that, 15 different crops produced. Maize, teff and sorghum were the dominant crops cultivated in lowland, midland and highland agro-ecology (Figure 5). Mean land allocated for annual crops were higher than those were utilizes for perennial crops in all agro-ecology. An average of land in all agro-ecology used for maize, teff and sorghum cultivation were 77.73 ha, 31.87 ha and 17.17 ha, respectively (Table 6). The ANOVA in ranks test showed that there were highly significant ($p<0.001$) difference among lowland, midland and highland in allocating land to crops.

The study results agrees with the finding of Alemu *et.al.*, (2016) who stated that maize, teff and sorghum was the major crops grown in southern Ethiopia. Teshager, (2013) who reported that the mean land allocated for annual crops was higher than utilized for perennial crops in his study area. The result of the present study was also in agreement with the findings Teklu *et.al.*, (2009) of the previous reports in other region of Ethiopia who reports that maize, teff and sorghum, and others root and tuber crops, such as enset *(Ensetventricosum*), mango, banana, taro, Oromo potato (*Colcusedulis*) are widely cultivated in upper part of the Nile.

Table 6. Farmland allocation proportion among different crops

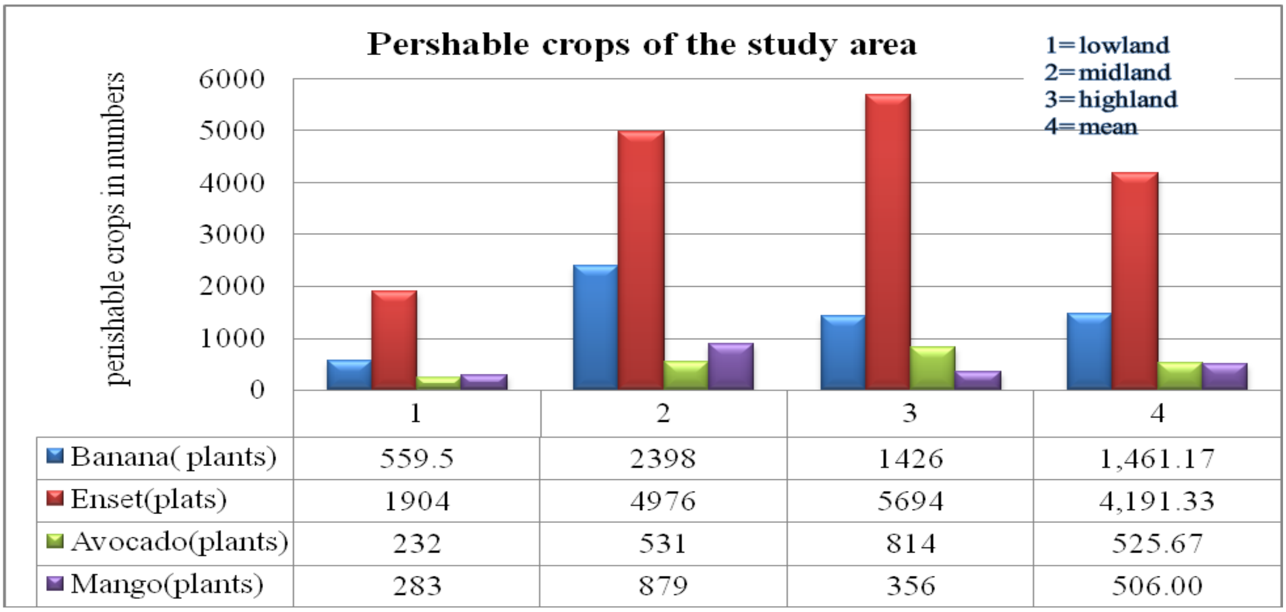
	Agro ecology				**Chi square result**		
Crops types	**Lowland (ha)**	**Midland (ha)**	**Highland (ha)**	**A.E Mean**	***df***	**x^2 value**	**sig.**
Maize	38	131.5	63.7	77.73	22	55.674[a]	$p<0.001$
Teff	23.25	50.48	21.78	31.84	22	99.310[a]	$p<0.001$
Sorghum	12.87	27.19	11.46	17.17	16	78.411[a]	$p<0.001$
Burly		2.625	0.25	0.96	6	15.481[a]	$p<0.05$
Wheat	1.94	4.625	1.06	2.54	10	16.132[a]	$p<0.05$
Millet		1		0.33	2	4.461[a]	$p<0.05$
Coffee	8.71	15.77	16.44	13.64	28	56.086[a]	$p<=0.001$
Tomato	0.32	5.5	2.38	2.73	12	17.388[a]	$p>0.05$
Potato	0.19	0.315	2.81	1.11	12	26.1.7[a]	$p<0.05$
Banana(plants)	559	2398	1426	1,461.	50	83.771[a]	$p<0.05$
Enset(plants)	1904	4976	5694	4,191.33	64	116.583[a]	$p<0.001$
Avocado(plants)	232	531	814	525.67	46	75.026[a]	$p<0.05$
Mango plants	283	879	356	506.00	38	59.211[a]	$p<0.05$
Paper	11.69	25.5625	1.1875	12.81	16	153.715[a]	$p<0.001$
Taro	0.7505	14.15	0.5	5.13	12	37.998[a]	$p<0.001$

Note; a indicated in the table that “n” cells (n%) have expected count less than 5. The minimum expected count is .18.



	Maize	Teff	Sorghum	Burly	Wheat	Millet	Coffee
🟦 lowland	38	23.25	12.87	0	1.9375	0	8.705
🟥 midland	131.5	50.475	27.1875	2.625	4.625	1	15.7725
🟩 highland	63.7	21.7825	11.4625	0.25	1.0625	0	16.44
🟦 agro-ecology mean	77.73	31.84	17.17	0.96	2.54	0.33	13.64

Figure 5. Farm land allocation among different crops



	1	2	3	4
🟦 Banana(plants)	559.5	2398	1426	1,461.17
🟥 Enset(plats)	1904	4976	5694	4,191.33
🟩 Avocado(plants)	232	531	814	525.67
🟪 Mango(plants)	283	879	356	506.00

Figure 6 Perishable crops cultivated in numbers

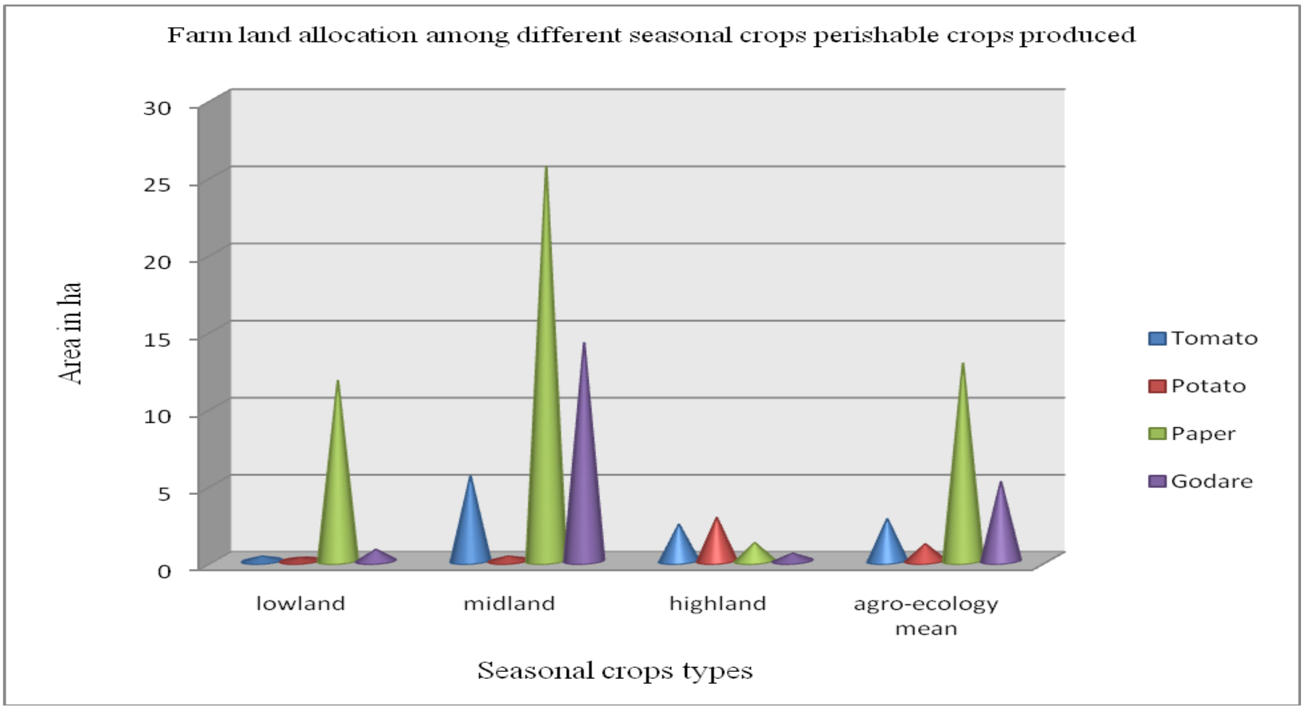


Figure 7.Perishable crops cultivated by ha

Hot paper and taro were also the common crops in the area. The result showed that land allocation to hot paper and taro were the highest among others seasonal crops. Enset and Banana was the highest in numbers of plants within annual crops (Figure 6 and 7). The kruskal-wallis result showed that was highly significance ($p<0.001$) difference among agro-ecology in land allocation as well as by numbers of plants. Concerning potato, Banana, Mango and Avocado there were significance ($P<0.05$) difference among agro-ecology (Table 6). So far there were no significance ($p>0.05$) difference among agro-ecology in land allocation for tomato.

The result of this study agrees with the findings of Alemu *et.al., (*2016) who reported that, at high altitude, Enset were common and high in numbers of plants and numbers of farmers producing. These results were also in agreement with the findings Teklu *et.al.*, (2009) of the previous reports in other region of Ethiopia who reports that root and tuber crops, such as Enset *(Ensetventricosum*), mango, banana and taro are widely cultivated in upper part of the Nile.

4.1.2.4. Farming systems characteristics of the study area

Mixed cropping farming describes the farming system of the area. Mixed cropping farming systems and mono cropping farming system characterized majority of crops produced in the study area. The study result revealed, 71.2% of maize in lowland, 39.5% in midland and 11.45% in highland agro-ecology were characterized through mixed cropping farming systems and the results of the table indicated 28.8% of maize in lowland, 58.27% in midland and 88.54% in highland were characterized through single cropping farming systems. There were highly significance (*p<.001*) difference among lowland, midland and highland agro-ecology in farming systems of crops. This showed us the farming systems of the study area was independent within agro ecology and not influenced each other (Table 7).

The study of the situation in support of Teklu *et.al.,* (2009) who stated that cereals based single cropping systems encompasses the cultivation of the major cereals in the basin including maize, teff, sorghum and many others.

Table 7. Farming system characteristics of the area

	Agro-ecology															
	Lowland					Midland					Highland			Chi Square results		
Crop types (%)	Mixed	Inter	Sequential	Strip	Sole	Mixed	Inter	Sequential	Relay	Sole	Mixed	Inter	Sole	Value	*df*	Sig.
Maize (%)	71.2				28.8	39.57	2.16			58.27	11.45		88.54	65.837^a	6	.000
Teff (%)	6				94	0.85		0.85		98.29			100	21.844^a	6	.001
Sorghum(%	2.33				97.67	4.3				95.69	1.92	1.92	96.15	18.783^a	6	.005
Barley (%)										100			100	7.777^a	2	.020
Wheat (%)				9.1	90.9	5.88				94.12	20		80	14.499^a	6	.025
Millet (%)										100				4.461^a	2	.107
Coffee (%)	14.82	7.41	7.41	7.41	62.95	36.08	5.15			58.76	13.04		86.96	44.745^a	12	.000
Tomato (%	33.33				66.67	62.96				37.04	25		75	11.747^a	4	.019
Potato (%)	100					75				25	10		90	15.275^a	4	.004
Banana (%)	72.41	3.45	17.24		6.9	77.77	5.55			16.66	85.96		14.04	28.568^a	10	.001
Enset (%)	73.33		10		16.66	75.78	2.11		1.05	21.05	91.52		8.47	25.197^a	12	.014
Avocado(%	73.91		13.04		13.04	79.22	1.29	1.29		18.18	94.11		5.88	23.237^a	10	.010
Mango (%)	69.23	3.85	15.38		11.54	84.37				15.63	97.61		2.38	28.909^a	8	.000
Hot paper (%)	42.86				57.14	24.73				75.26	16.66		83.33	108.317^a	4	.000
Taro (%)	80				20	54.17				45.83	33.33		66.66	13.627^a	4	.009

Note; a indicated in the table that “n” cells (n%) have expected count less than 5. The minimum expected count is .18.

4. 1.2.4.1. Purpose of produced crops

The results of the survey revealed that purpose of producing different crops was varies among households in lowland, midland and highland agro-ecology. The results of the analysis on (Table 8) showed that the major objective of producing crops in the study areas were for income sources and for personal consumption. About 62% in lowland, 63% in midland and 64% in highland of maize produced for Consumptions purposes. The chi-square results indicated that there were highly significance (*$p<0.001$*) difference among lowland, midland and highland agro-ecology of purposes of producing crops. The results indicated that majority of each crops produced for sale purposes and for personal consumption. The result of the present study was also in support of Yisehak *et.al.,* (2013) who stated that of major purpose of producing crops at rural area were for sale and for consumptions in Jimma zone, southwestern Ethiopia.

.

Table 8. Purpose of Production

	Agro –ecology													
	Lowland				**Midland**				**Highland**			**Chi square**		
Crop types	Animal feed	Subsistence	Personal consumption	For sale	Animal fee	Subsistence	Personal consumption	For sale	Subsistence	Personal consumption	For sale	x^2Value	*df*	Sig.
Maize (%)		1.9	62.75	35.29	1.45	19.57	63.77	15.22	17.02	64.89	18.08	25.153^{a}	8	.001
Teff (%)			78.8	21.2	1.61	8.87	83.87	5.65	7.46	77.61	10.45	51.865^{a}	8	.000
Sorghum (%)				94.87	3.37	7.86	88.76		5.45	81.81	12.72	24.300^{a}	8	.002
Wheat (%)			100				100		5.55	77.77	16.66	7.822^{a}	6	.251
Barley (%)							100					10.213^{a}	2	.006
Millet (%)					33.3		66.66					3.334^{a}	4	.504
Coffee (%)			72.41	27.59	3.19	14.89	81.91		1.33	82.22	4.44	48.660^{a}	8	.000
Tomato (%)			100		3.5	7.14	89.28		28.57	71.42		11.975^{a}	6	.063
Potato (%)			100		4.54		95.45		12.5	75	12.5	12.919^{a}	8	.115
Banana (%)			83.33	16.66	4.68	7.81	85.93	1.56	11.53	88.46		26.415^{a}	8	.001
Enset (%)			90	10	1.47	5.88	92.65		11.11	81.481	7.41	29.3.9^{a}	8	.000
Mango (%)	3.44	3.44	75.86	17.24	1.41	5.63	92.95		15.38	82.05	2.56	28.153^{a}	8	.000
Avocado (%)			79.16	20.83	1.61	6.45	91.94		12.9	87.1		32.108^{a}	8	.000
Hot paper (%)			100		3.96	10.89	83.16	1.9		30.43	69.56	140.328^{a}	8	.000
Taro (%)			100		6.66	93.33			25	50	25	22.342^{a}	6	.001

Note; a indicated in the table that “n” cells (n%) have expected count less than 5. The minimum expected count is .18.

4.1.2.4.2. Production proportion uses as income sources of the respondents

The results of Table 9 indicated respondents production amount of crops uses for income purposes. The study results showed us from all crops solded for income purposes, maize, Teff, sorghum and coffee had the highest. The amounts of crops solded that accounted to (25-50%) ranges were higher than other percentages ranges in lowland, midland and highland agro ecology. The chi-square results indicated that there were highly significance ($p<0.001$) difference among lowland, midland and highland agro-ecology (Table 10) in amounts of crops solded as an income sources.

The results of the present study agrees with the findings of Yisehak *et.al*,(2013)who stated that the major sources of incomes for rural household was crop production which accounted 29% in Seka 30% in Manna and 25% in Dedo of Jimma zone, south western Ethiopia and statistical difference was not observed among lowland, midland and highland in his findings. The result of the present study was also in support with the findings of Teshager*et.al;* (2013) who stated that majority of the respondents in the study area of their source of income is from crop production in southwestern Ethiopia.

Table 9. Proportion amounts of production uses as income sources

	Agro ecology														
	Lowland					Midland					Highland				
Crop types	<25%	26-50%	51-75%	>76%	Other	<25%	26-50%	51-75%	>76%	other	<25%	26-50%	51-75%	>76%	other
Maize	30.6	44.4	13.9	11.1		10.3	76.1	9.4	1.7	2.6	20.6	67.7	11.8		
Teff	19.35	51.61	25.81		3.2	26.5	22.22	6.84	0.86		38.71	45.16	12.9	3.22	
Sorghum	44.44	55.55				95.24	4.76				25	54.17	20.83		
Wheat	75	25				66.66	16.67	16.67			16.67	50	33.33		
Barley						100									
Millet						66.66	3.33								
Coffee	20	25	25	30		5.41	56.77	16.23	21.62		19.05	66.67	14.29		
Tomato		100					75	25				100			
Potato						50	25		25			100			
Banana	62.5	12.5	6.25	18.75		44.44	27.78	5.56	22.22		21.74	69.57	4.35		4.35
Enset	66.67	13.33	13.33	6.67		81.82	18.18				18.18	72.73		9.09	
Mango	100					75	25				18.18	81.81			
Avocado	80	10	10			54.55	36.36		9.09		20	70	10		
Hotpaper															
Taro				100		25	75					66.67	33.33		

Table 10. The chi-square results of production uses as income sources of the respondents

Crop types	**Chi square results between Agro- ecology**		
	Value	*df*	*sig*
Maize	35.696[a]	10	.000
Teff	28.182[a]	10	.002
Sorghum	43.242[a]	6	.000
Wheat	6.253[a]	6	.395
Barley	2.215[a]	2	.330
Millet	3.334[a]	4	.504
Coffee	20.293[a]	8	.009
Tomato	4.868[a]	4	.301
Potato	7.998[a]	6	.238
Banana	32.106[a]	10	.000
Enset	34.074[a]	8	.000
Mango	20.504[a]	4	.000
Avocado	19.028[a]	8	.015
Hot paper	40.362[a]	10	.000
Taro	8.726[a]	8	.366

4.1.3. Trees on farmland

4.1.3.1. Distribution, location and pattern of farmland trees

Trees on farmland depict the characteristics of tree on farmland of the area. The results of (Table 12) showed *Eucalyptus, Cordia africana* and *Grevillea robusta* were common trees in the farmland of the study area. The study result indicated, majority of *Eucalyptus* vegetation around the farmland were characterized by scatter and dense vegetation. Proportionally 60% of *Eucalyptus,* vegetation's in lowland was dense and 65% in midland and 59% in highland of *Eucalyptus* was characterized by scatter vegetation. However, large number of *Cordia africana* and *Grevillea robusta* in farmland characterized by scattered vegetation. The results of study indicated that there were practices of managing trees in and around farmland. This practice indicated that trees could found in farmland in various forms of spatial and temporal arrangements for different purposes.

The results of the study in support of Tesfaye, (2005) who stated that one of the features of trees management in farm land is that, the biological characteristics of trees are often taken in to account to determine where it should be grown and for instance, trees can contribute positively to agricultural crops are grown dispersed in crop fields. While trees that compete with crops planted separately in block arrangements. According to Arnold and Dewees,(1995) depending on the type of ecological settings, trees would arranged in different patterns on farmlands as: planted on fallow land, trees grown in homestead areas, tree growing along boundaries, intercropping on arable land and mono cropping on arable lands. According to Kindt *et.al*., (2005) the practices of managing trees in and around the farmland has included in farming systems for the roles of preventing degradation through agro-forest ecosystems on farms.

Table 11. Vegetation coverage of the study area

Agro ecology		Eucalyptus(ha)	Cordia africana(ha)	Grevillea robusta	Eucalyptus(No.)	Cordia africana(No.)	Grevillea robusta(No)
Lowland	Mean	.090	0	.076	9	6	23
	Sum	4.69	0	3.938	464	281	1203
Midland	Mean	.263	0	.017	11	11	15
	Sum	36.803	0	2.375	1557	1540	2129
Highland	Mean	.112	.003	.007	2	5	2
	Sum	11.463	.250	.688	179	434	149
Total	Mean	.18	.001	.024	8	8	12
	Sum	52.953	.250	7.000	2200	2255	3481

Table 12. Vegetation structure in farm land.

		Eucalyptus			*Cordia africana*			*Grevillea robusta*		
		Vegetation structure in farm land			Vegetation structure in farm land			Vegetation structure in farm land		
Agro-ecology		Scatter %	Dense %	Boundary %	Scatter %	Dense %	Boundary %	Scatter %	Dense %	Boundary %
Lowland		37.14	60	2.86	65.52	27.59	6.89	44	12	44
Midland		65.46	23.64	10.9	94.87	5.13		75	12.5	12.5
Highland		59.38	40.63		55.56	44.44		100		
Chi-square test	Value	37.775^{a}			57.111^{a}			80.557^{a}		
	df	6			8			8		
	Sig.	.000			.000			.000		

4.1.4. Respondent resources for farming

4.1.4.1. Livestock holding

Livestock was one of the resources owned by a respondent, which contributes for farming. The results showed that average livestock in all agro ecology were 1-3 per household except chicken. The study result also showed that the overall mean of caws, Heifer, sheep and Chicken owned per the household of midland agro-ecology farmers were higher, when compared to that of lowland and highland agro-ecology (Figure 8). Calves, Donkey and Hoarse average numbers were equal in lowland, midland and highland agro-ecology. Generally, the results indicated that at midland agro-ecology of livestock holding per household were relatively higher. This showed as majority of the respondent kept livestock for different purposes.

The results of the survey in support with the finding of Addisu *et.al.*, (2012) who stated that on average 85% of households keep two cattle for tillage, threshing and manure production. Donkey and Hoarse kept for transportation and for income source. Households for sale and household consumption in rural areas of Ethiopia also keep sheep, goat and chicken. The result of the present study was also in support with the findings of Bedada *et.al.*,(2014) of the previous reports in other region of Ethiopia who stated that the overall mean of cows(2), oxen(2), heifer(1) and calf(1) owned per household.

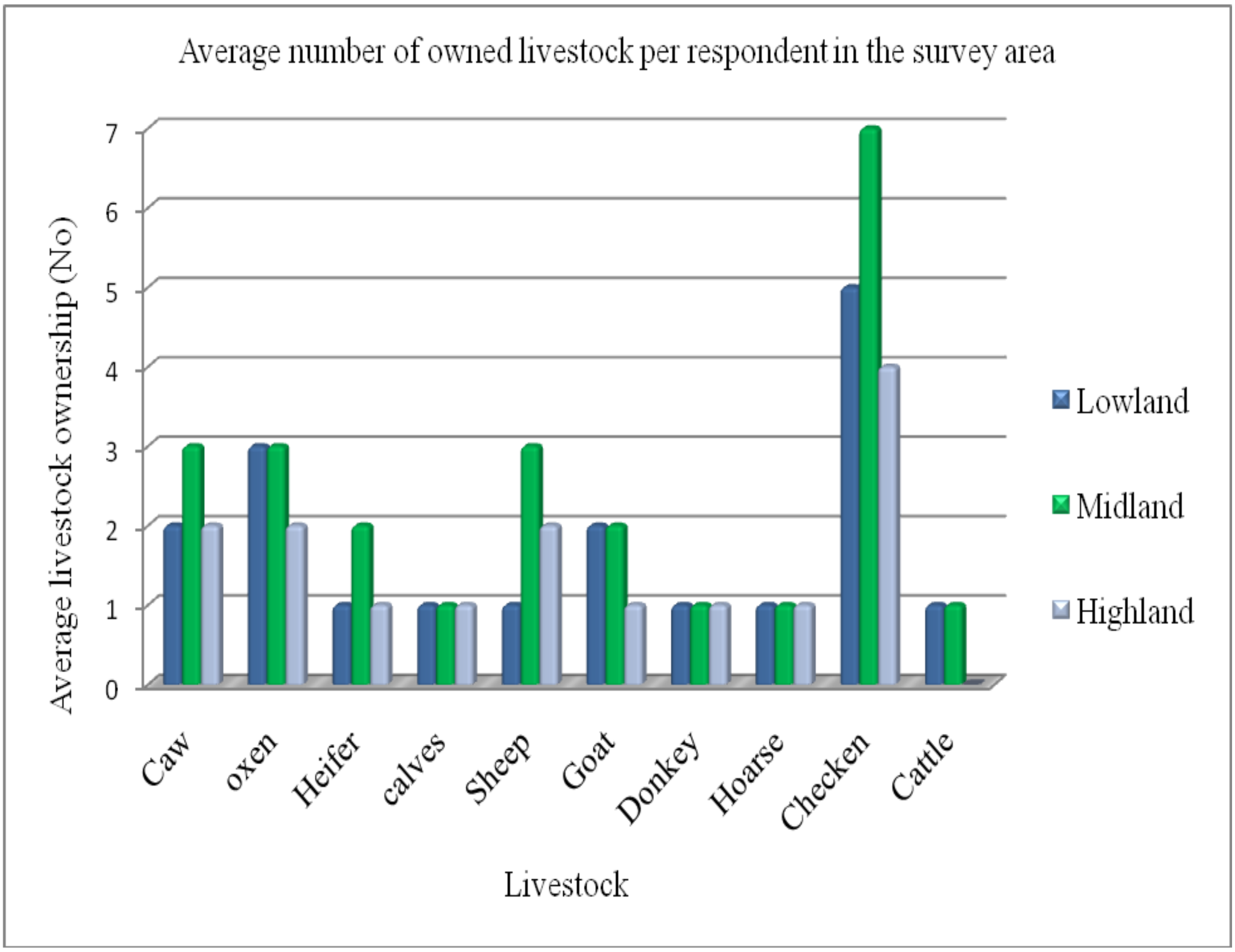


Figure 8.Average numbers of owned livestock per participants in the study area

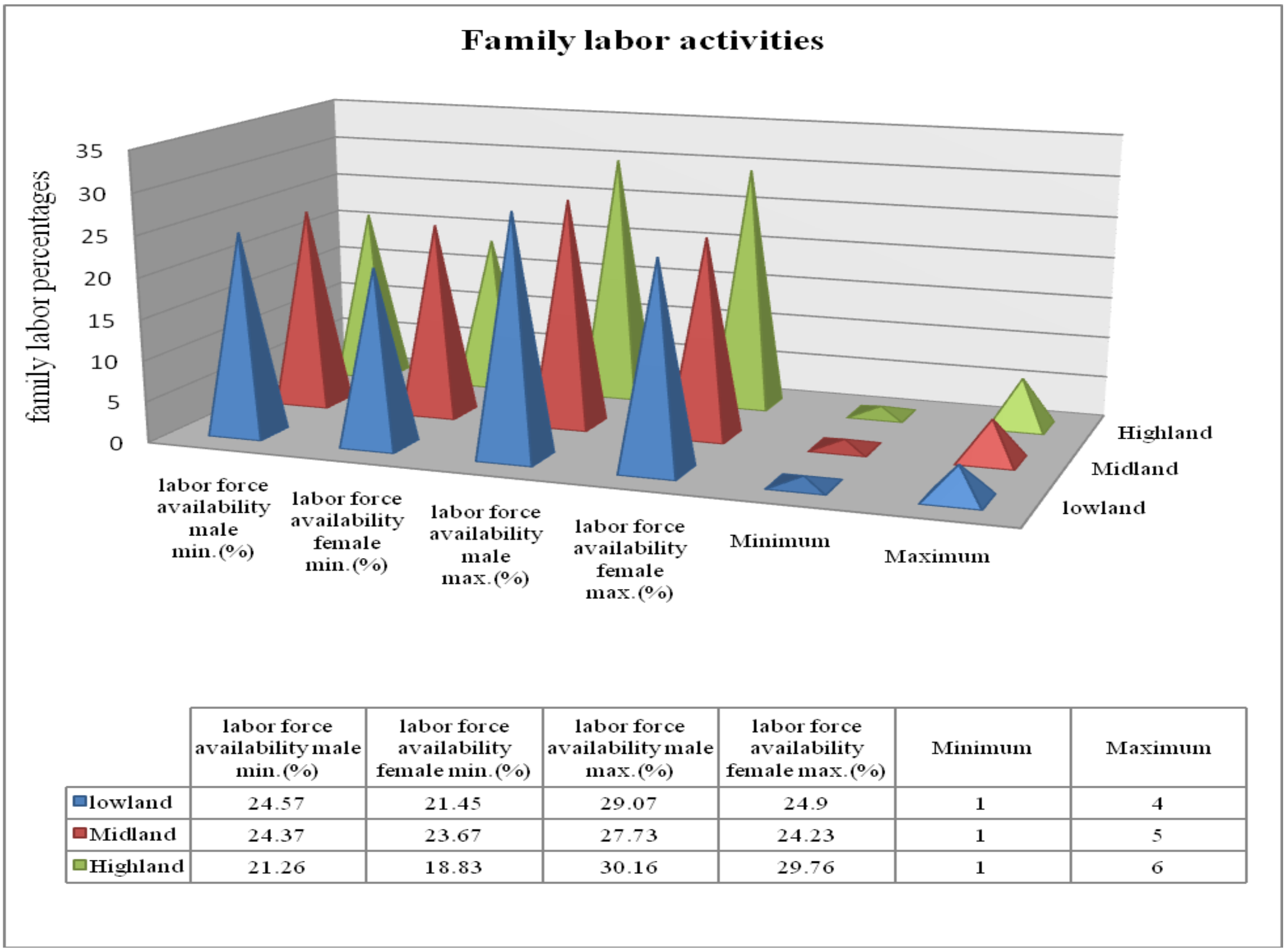
4.1.4.2. Family labor activities for farming

The family members' labor force of the Survey provides estimates of family member involved to agricultural activities. The results showed that males time involved to agricultural activities was higher than female time involved to agricultural activity at maximum as well as at minimum time in lowland, midland and highland agro-ecology (Figure 9) and some of family member involved to agricultural activity at minimum time were partial time. The results of chi-square indicated that there were highly significance *($p>0.004$)* difference among lowland, midland and highland agro-ecology at family member minimum time involved to agricultural activities. However at majority of family member involved to agricultural activity at maximum time involvement were full time and the results of chi - square indicated that there were non-significance*($p=0.368$)*difference among lowland, midland and highland agro-ecology at family member maximum time involved to agricultural activities(Table 12).

This is agrees with the finding of Takane,(2008) who reported that family labor force to agricultural activities in rural area accounted totally 88%. The result of the present study was also in supported with the findings of Fofana *et.al.,* (2011) who stated that averagely from household size (48%) of male and (47%) of female was available for farm work in Mali.

Table 13.Participant family members' time involved to agricultural activities

Family members labor time division		**Agro-ecology**			**Chi square results**		
		Lowland	Midland	Highland	Value	Df	*Sig.*
Minimum involvement	Fully (%)		11.82	23.94			
	Partially (%)	92.86	86.36	73.24	19.341[a]	6	*.004*
	Not involved (%)	7.14	1.82	2.81			
Maximum involvement	Fully (%)	100	93.79	94.68	6.511[a]	6	*.368*
	Partially (%)		5.43	5.3			
	Not involved (%)		.78				



	labor force availability male min.(%)	labor force availability female min.(%)	labor force availability male max.(%)	labor force availability female max.(%)	Minimum	Maximum
🟦lowland	24.57	21.45	29.07	24.9	1	4
🟥Midland	24.37	23.67	27.73	24.23	1	5
🟩Highland	21.26	18.83	30.16	29.76	1	6

Figure 9.Family labor activities

4.1.4.3. Wealth category and assets of the respondent

Table 14 indicated the wealth category of the respondent that is relevant to understand the capacity of farmers for agricultural activities. According to the results in lowland agro-ecology well endowments of the respondent were 40% and poor endowment of the respondent were 27% and higher than midland and highland agro-ecology. However, midland medium wealth category of the respondent was higher than lowland and highland agro-ecology. The results indicated that majority of the respondent in midland and highland agro-ecology was in the range of medium wealth category except majority of the respondents in lowland agro-ecology were in the range of well endowment (Table 14). There were significance difference (*$p<0.05$*) among lowland, midland and highland agro-ecology of wealth category of the respondent.

The result of the present study not in supported with the findings of Fofana *et.al.,* (2010) who stated that poor endowment number of the respondent was higher than well endowment in Bougouni and koutiala districts.

Table 14. Distribution of wealth index rankings of households of the Districts

Wealth index	Highland(N=102)		Lowland(N=52)		midland(N=140)		Chi Square		
	Freqncy	%	Freqncy	%	Freqncy	%	*df*	X^2	*Sig.*
well endowment	35	34.3	21	40	41	29	4	13.187^a	$P<0.05$
poor endowment	24	23.5	14	27	18	13			
Medium	43	42.2	17	33	81	58			

The data generated Showed that most of the families in the study area that about 90.4% in lowland, 86.4% in midland and 87.3% of the households have metal roof houses. The results indicated that larger proportion of the respondents had houses of metal roof and less than 15% of the respondents have grass thatched roof in lowland, midland and highland agro-ecology which both metal roof and grass thatched roof made mud-walled(Table 15). This is agrees with findings of Kassie, *et.al.,*(2012) who reported that majority of Angolans live in Iron roof houses and houses are important assets. Apart from being a necessity, they also indicate the financial status of the farmers.

The results of the analysis of table 14showed revealed that large number of the respondent have an access of Radio and phone. The percentages of Radio were accounted 67.3% in lowland which higher than midland and highland agro-ecology. Nevertheless, 68% of the respondent in midland had phone that were higher than lowland and highland agro-ecology. In the study area, small number of respondent (2) reported to have a car of their own in lowland and highland agro-ecology (Table 15). The lower number of respondents reported to have car, motor cycle and milling of their own in study area.

The results of study agreeing with findings of Kassie, *et.al.,* (2012) who stated that 1.3% of the 1108 sample farmers reported to have a car of their own in Angola and Zimbabwe as well as TV(<5%) from sampled households in Malawi and Mozambique and Milling and

Motor cycle < 2% were reported in Malawi, Mozambique and Zimbabwe. The results of the present study agrees with the findings of Gafsi,(2006) who stated a major approach to strategic resources to mobilized by the household was considered by incorporating a further two assets in addition to the classical assets *i.e.* physical and human assets which includes vehicles, tractors, bicycles, motorcycles, radios, televisions and others of family labor, non-family labor.

Table 15.Resource endowments of the sample population and house of the respondents

	Agro –ecology								
	Lowland(N=52)		**Midland(N=140)**		**Highland(N=102)**		**Chi-square results**		
Asset types	Frequencies	%	Frequencies	%	Frequencies	%	value	*df*	*sig*
Car	1	1.9			1	1	2.284^{a}	2	*.319*
Motor Cycle			3	2.1	2	2	1.105^{a}	2	*.576*
Milling	1	1.9	1	0.7			1.890^{a}	2	*.389*
Television	9	17.3	10	7.1	2	2	13.953^{a}	4	*.007*
Radio	35	67.3	67	47.8	66	64.7	12.439^{a}	6	*.053*
Phone	34	65.4	80	57.2	68	66.7	6.663^{a}	6	*.353*
Metal roof houses	47	90.4	121	86.4	89	87.3	.543a	2	*.762*
Grass roof houses	5	9.6	19	13.6	13	12.7			

4.1.4.4. Access to credit and agricultural input

The results of table 15 showed the financial access for farming. The results showed that only less than 8% of respondent had access to credit in lowland, midland and highland agro-ecology. Large number of the respondent had no credit access in all agro-ecology. The results revealed that the larger proportion of the respondent does not have access of credit and small number of respondent had access of credit. The study are not agrees with finding of Kassie, (2012) who stated that about 57% of the households in Zimbabwe have taken credit of different forms whereas only 3% of Mozambicans had done. However, the results of the study in support with the findings of Wiredu, *et.al.,* (2010) who stated that households in the study area had minimal access to credit and credit facilities and amount of credit received by farm households in the district is far lower than for those who had not received.

In agricultural production asset can contribute to production and hence to farmers’ wealth status. The results indicated greater than 83% of farmers in the study area took improved variety from co-operatives in lowland, midland and highland agro-ecology. However, small amount of the respondent took improved variety from districts agricultural office (Table 16).

Table 16. Farmers source of input and access of credit for production

	Agro-ecology			Chi square results		
Institution and access	**Lowland**	**Midland**	**Highland**	**value**	***df***	***sig***
Agricultural office	5.8	13.33	7.37	18.442[a]	12	.103
Research institute		.74	2.1			
University	1.9					
Model farmers			2.1			
Co operatives	88.5	83.7	84.21			
Union	3.8	2.22	4.21			
Got credit access	7.7	5.22	5.3	17.792[a]	8	.023
Not get credit access	92.3	94.78	94.68			

4.2. Moisture Content of Maize Grains and Weather Variables inside Stored Maize for Fungal Growth Potential

4.2.1. Moisture content of stored maize grain

The results of the study showed the mean initial moisture content of maize kernels in the high land agro-ecology of stored maize grain in *gombisa* of farmers' traditional storage was 16.83%. The mean initial moisture content of maize cobs (*gombisa*) of farmers' storage in midland and lowland agro-ecology was 17.5% and 17.83% respectively. The mean initial moisture content of maize kernels stored in the high land, midland and lowland agro-ecology of stored maize grain in collectors storage systems were 17.07%, 17.70% and 12.9% respectively.

The initial moisture content results of the present study in lowland, midland and highland agro-ecology in both farmers and traders storage conditions indicated that it was not in the range of safe moisture content (12-14%). This may leads and can favor to flourish both for

Penicillium species and for *A. flavus* growth. The study of the condition agrees with the findings of Charles (2012) who stated that maize grain stored with moisture ranged from 16 to 18% could favor to flourish both *Penicillium* species and *A. flavus* growth. However, the initial moisture content results of sacks storage of traders in low land agro-ecology were in ranges of safe moisture content that was inappropriate for fungi species. Jelle, (2003) stated that the ranges of save moisture content of the grains is (12-14%) and if the moisture content of the grains is more than safe, it leads for greater infection which facilitate fungi to grow (Reed *et.al.,* 2007). In fact, the recommendation of safe moisture content for maize grains store of Jelle (2003) contradicts with the recommendation of safe moisture content for maize grains store of Hettiarachchi, (2001). Jelle, (2003) stated that the ranges of save moisture content of the grains is ranged (12-14%) but Hettiarachchi, (2001) stated that maize with moisture content of 11.3% can be recommended as a save level of moisture content for storage, when the moisture content 11.3% corresponding to 70% Equilibrium relative humidity and sale devoid of fungal growth and accumulation of aflatoxins. According to Hell *et.al*., (2000) and Giorni*et.al*., (2009) the initial moisture content of the grain stored is one of the most important factors that leads development of fungal growth inside store. The results of initial moisture content of the study may susceptible to mold and this agrees with the findings of Brew (2003) who reported that the higher the moisture content of the stored grain, the more susceptible to mold and insect deterioration. Charles, (2012) stated that maize grain stored with moisture ranged from 16 to 18%can favor to flourish both *Penicillium* species and *A, flavus* growth.

In maize, for instance, it was determined that a storage moisture content of 13% is sufficiently low to prevent fungus development. Thus, development of fungi can affected by moisture content of the product, storage time, degree of fungal contamination rate prior to storage and insect and mite activity that might facilitate fungi dissemination and delayed harvest increased mold incidence and insect damage.

Grain stored in storage containers lost moistures as storage time increased to 60 days reaching values 11.4 up to 13.5% ranges in lowland, midland and highland agro-ecologies across storage structure except the 10.91% moisture content results recorded in lowland agro-ecology of maize grains in sacks storage of trader storages (Table, 17). This indicated that the results of the differences in the initial moisture content of the grain could be due to exposure of grain to ambient temperature and due to nature of storage systems. The results of the study agree with the findings of Dubale *et.al,* (2014) in Jimma zone southwestern Ethiopia, who reported that as storage duration increases, the grains moisture content decline. The study of the conditions not leads development of fungi's during 60 days of storages period. Because the results of moisture content within two months of storage durations showed in ranges of safe moisture content (12-14%) as stated by Jelle,(2003), except maize grain stored in lowland agro-ecology in sacks of trader storages, which were below the save moisture content and leads to make the grain unfit for consumption. In addition, as storage duration exceeds 120 days the results of the moisture content of maize grain inside *gombisa* and sacks ranged 11.1% up to 13.2% in lowland, midland and highland agro-ecologies.

However, during the days of 180 days storage duration, the results of stored maize moisture content recorded inside *gombisa* for farmer and traders' storage system ranged 12 up to 13.8% in lowland, midland and highland agro-ecology except 15.21% recorded in lowland agro-ecology of farmer storage. The results of moisture content after four month of the grain stored inside *gombisa* of farmer storage and trader storage showed that safe moisture content level in all agro- ecology except the results recorded in grain stored in *gombisa* in lowland agro-ecology. This indicated that the results of the differences in the initial moisture content at different storage duration could be due to exposure of grain to different ambient temperature due to storage structure.

It has reported previously that storage structures differ in their ability to protect grains from moisture movement and consequently fungal development. Hell, *et.al,* (2000) found that some types of farmers' storage structures provided conditions that were more conducive to fungal infection in West Africa. High moisture content generally favors the development of storage fungi (Jelle, 2003) and low moisture content make the grain unfit for consumption. Therefore, poor postharvest practices particularly in ability to manage moisture content could be the major factor for mold infection, deteriorations and loss of the crop. In relation to this, several fungal species are favorable with recorded moisture content.

Table 17, Moisture content (%) of stored maize under different actors storage conditions

Actors	Agro-ecology	Initial Loading stage	Two month storage	Four months storage	Six months storage
Farmers	High land	16.83	11.60	13.14	12.27

	Midland	17.50	13.57	13.23	13.82
	low land	17.83	11.43	12.69	15.21
Collectors	High land	17.07	13.02	11.97	12.29
	Midland	17.70	12.01	11.11	11.86
	low land	12.90	10.91	11.42	13.17
Whole seller	Jimma Town	13.00	11.34	11.50	12.60

4.2.2. Temperature and relatives’ humidity in stored Maize

4.2.2.1. Temperature and relative humidity of grain inside farmers’ traditional storage structure

It is noted that from (Fig. 10, 11 and 12) the average temperature and relative humidity recorded inside maize grain stored in farmer traditional storage had ranged from (22 up to 27°C) and (20 to 40 %) respectively at lowland agro-ecology. At middle land agro-ecology the temperature and relative humidity had ranged (18 up to 24 °C) & (35 up to 70%) respectively inside farmer traditional storage within the first two months of storage duration (January and February). The lower numbers of temperature (13 up to 24°C) and relative humidity (38 to 85%) recorded inside maize grain stored of farmer traditional storage at highland agro-ecology at the same storage duration. The study results during two to four months(March and April) of storage duration showed the temperature and relative humidity of maize grain stored inside farmer traditional storage had ranged (27-30°C)and (25-55%) respectively at lowland agro ecology. The temperature and relative humidity inside maize grain stored at midland and high land agro ecology was ranged from (18 up to 26°C) and (25 up to 68%) respectively to the end of storage duration(June).

The study result indicated that there were fluctuation of temperature and relative humidity of maize grain stored inside farmer traditional storage at lowland, midland and highland agro ecology. During the two months and half of storage duration, the temperature of maize grain stored inside farmers’ traditional storage increased in lowland, midland and high land agro-ecology (Fig.10, 11 and 12). Comparatively within agro-ecology the temperature at lowland was higher than midland and highland agro-ecology (lower temperature was recorded). However, after two months of storage duration, the temperature inside farmers' traditional storage decreased up to the end of storage duration in all agro-ecology. Compare to others, lower temperature ranges recorded in highland agro-ecology than lowland and midland agro-ecology (Fig. 10, 11 and 12). The results of relative humidity trends of maize grain stored inside farmers' traditional storage within two and half months of the storage duration indicated that decreased before 2 ½ months and increased after up to the end of the storage duration. Relatively the relative humidity ranges of the storage before 2 ½ months storage duration were high in highland than midland and lowland (lower relative humidity recorded) and also relatively after 2 ½ months of the storage duration up to the end of storage duration, the relative humidity recorded in lowland was lower than other agro-ecology.

The fluctuation of temperature and relative humidity inside farmers and collectors storage may due to ambient temperature and relative humidity reaction with temperature and relative humidity inside storage. The results of the study agree with Samuel *et al.*,(2011) who stated that, even after drying, maize grain harvested in tropical countries retained a certain amount of moisture, and when exposed to air, exchanges of moisture between the maize grains and surrounding occur until the equilibrium reached. Beside this, fluctuation of temperature and relative humidity in tropical countries it accelerates rapid multiplication of molds and insects, which facilitate further spoilage of grain(Yakubu, 2009). The trends of study indicated the temperature and relative humidity recorded in maize grain stored inside farmer traditional storage at lowland agro ecology favoring *Aspergillus* species as stated by Brennan et al., (2003) who founds temperature ranged within 20-30°C were optimal and fast growth were occurred for *Fusarium* species. The result of present study in agrees with the finding of Dubale *et.al*,(2014) who stated that the temperature ranges from (21.30 up to 35°C)and relative humidity ranges from (30 up to 54%) was optimal to flourish for *Aspergillus* species with *gombisa* of farmer traditional storage in lowland agro-ecology in selected districts of Jimma zone, south western Ethiopia

According to Homedork *et.al.,* (2000) the temperature and relative humidity of storage under condition of 25°C/90%, are in appropriate for seed quality and grain product, as well as the infection level of fungi had increased and have potential to flourish. Especially *fusarium* species over grown by computing storage fungi, mainly *Aspergillus* species and *pencillium* species have favoring under this condition. Homedork *et.al.*, (2000) observed that and recommended the grain stored temperature and relative humidity of storage under 25°C/73% storage condition are suitable for grain but not for seeds and under the condition of 15°C/56% are the most appropriate for storage of grain to obtain quality of grain and seeds and the mycotoxin level is low. This recommendation indicted that the results of temperature and relative humidity recorded from storage structure across actors and agro-ecology of the study are favoring fungal species during storage duration.

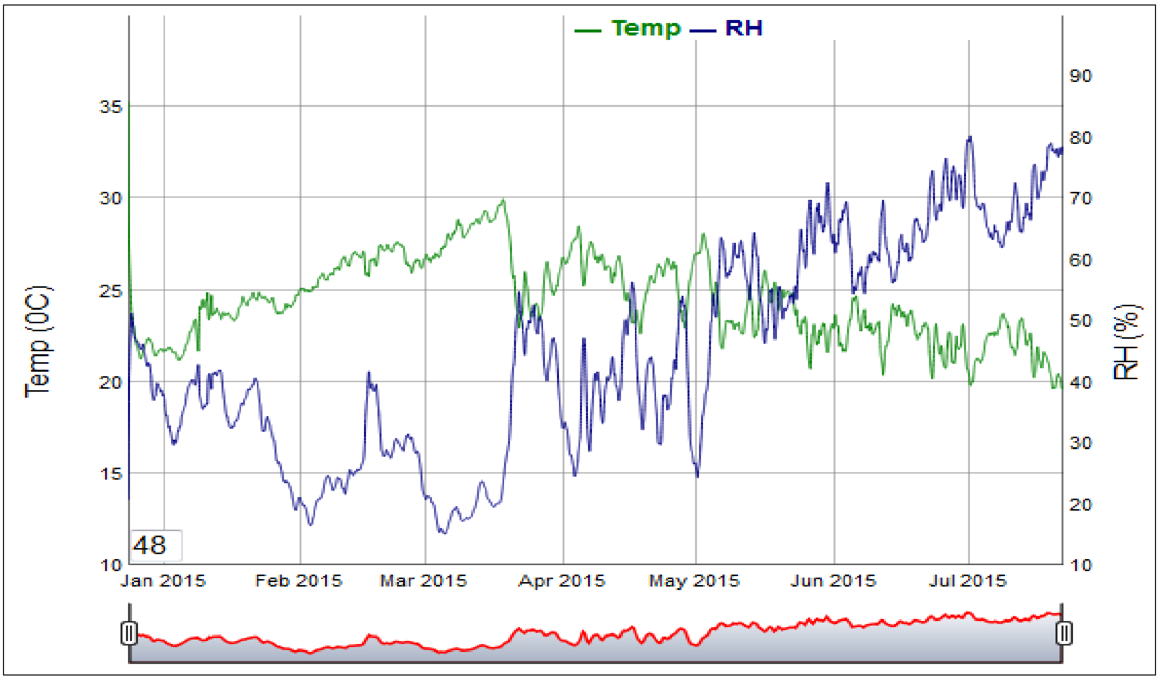


Figure 10.Temperature and relative humidity trend inside farmer traditional maize storage system at lowland agro-ecological setting.

Where, Temp = temperature in ^{0}C, RH= relative humidity in % and 48 role period

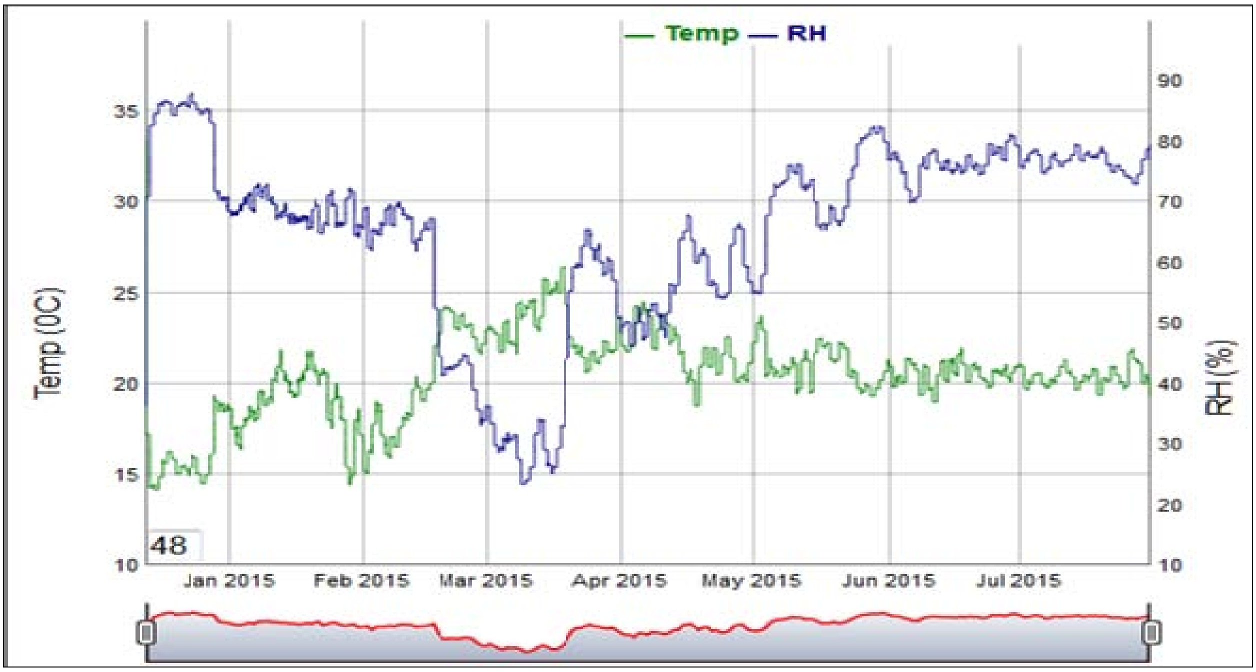


Figure 11. Temperature and relative humidity trend inside farmer traditional maize storage system at midland agro-ecological setting.

Where, Temp = temperature in ^{0}C, RH= relative humidity in percentage and 48 role period.

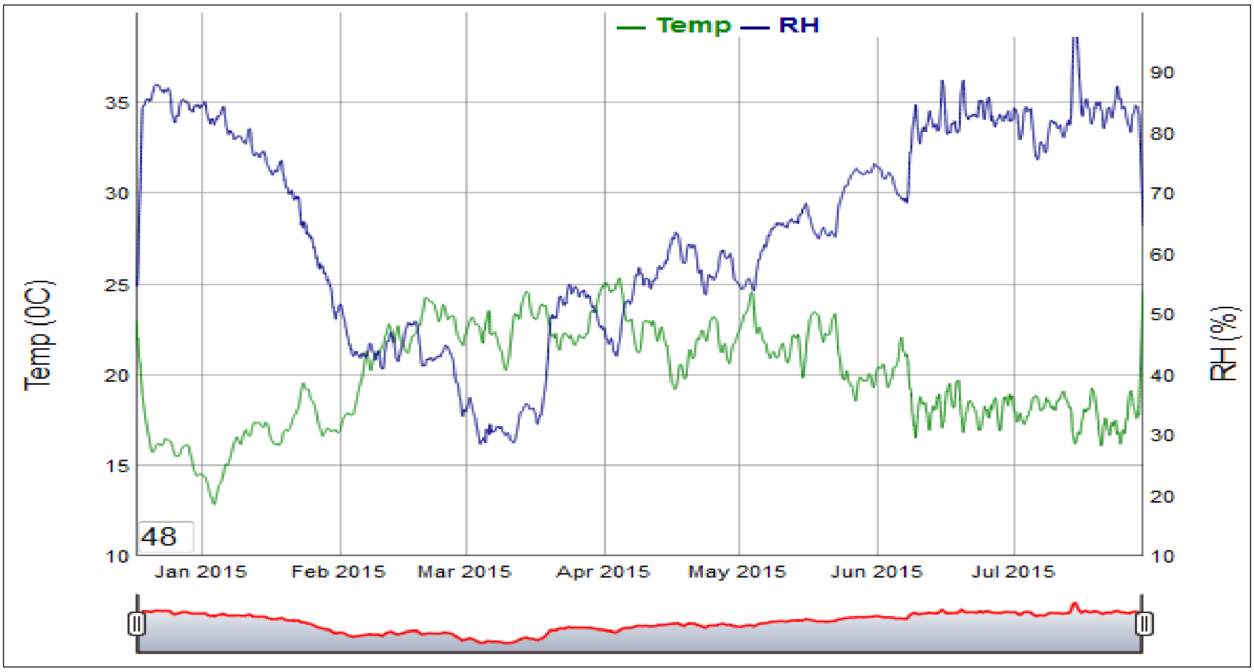


Figure 12.Temperature and relative humidity trend inside farmer traditional maize storage system at highland agro-ecological setting.

Where, Temp = temperature in ^{0}C, RH= relative humidity in percentage and 48 role period.

4.2.2.2. Temperature and relatives humidity grain inside stored maize under traders storage house

The temperature trends inside maize stored in collector storage systems at lowland, midland and highland agro-ecology becomes increased within two and half months of the storage duration and decreased after two and half months of the storage duration in all agro ecology. The trends of relative humidity inside maize stored in collector storage systems becomes decreased in lowland, midland and high land agro ecology within the first two and half months of the storage duration and increased after two and half moths of the storage duration in all agro ecology. The value of temperature and relative humidity of maize grain stored in whole seller storage systems was not this much fluctuated. Comparatively the temperature ranges of collector storage systems in lowland agro-ecology and whole seller storage system was high compared to high and midland agro ecology during the first two and half months of storage duration. However, in relative humidity value midland and high land maize grain stored in collector storage systems was higher than lowland agro ecology and whole seller storage systems.

Study finding showed that temperature and relative humidity of maize grain stored of collector maize storage system were (19 up to 28°C) and (45 to 68%) respectively at lowland agro ecology and (18 up to 25°C) and (64 to 86%) respectively at midland agro ecology within the first two months of storage duration(January and February). At highland agro ecology from (18 up to 25°C) and (75 to 90%) of temperatures and relative humidity were recorded respectively. During two to six months(March and April) of storage duration, the temperature inside maize grain stored of collectors' maize storage systems at lowland, midland and highland agro-ecology ranged from (23-29°C). The relative humidity was ranged (45-55%) at lowland, (50 up to 64%) at midland and (50-75%) at high land agro ecology during two to four months of storage duration were measured inside the storage and (50 up to 68 %) relative humidity were recorded to the end of storage duration(Fig. 13, 14 and 15).

The study trends of temperature and relatives humidity grain inside stored maize under collector storage house indicated fluctuations of temperature and relative humidity. According to the findings of Devereau *et.al., (*2002) the relationship between temperature and relative humidity in grain storage in the tropics, and results have revealed a direct relationship between, *i.e.* as temperature increases, grain will lose moisture to the surrounding air, thereby increasing the relative humidity. It has be observed that in most cereal grains, every 10 °C raise in temperature cause an increase of about 3 % in relative humidity (ACDI/VOCA, 2003). The result of temperature and relative humidity fluctuation of the study area promotes some species of fungi like *Aspergillus, fusarium and penicillin species*, which causes for grain nutrient loss. Shah *et al.,* (2002) had observed that the changing temperature and relative humidity not only promotes molds growth, but also causes considerable nutrient losses of the grain. The results of the study lead the growth of fungal pathogens which markedly influenced by temperature and relative humidity to which the commodities are exposed. According to Lacey *et.al.*, (1991) and Payne *et.al.,* (1988) the minimum, optimum, and maximum temperatures required for the growth of most storage fungi are 0 to 5°C, 30 to 33°C, and 50 to 55°C, respectively. This indicated that the results of the study that the commodity was stored at temperatures favorable for most fungal growth. Especially *Aspergillus* species, *A. flavus* may see on stored produce in the range of recorded temperature. Payne *et.al*,(1988) stated that, the parasitic (dependent) potential of *A. flavus* infecting maize grain remarkably increased at temperatures from 30 to 40°C. Similar investigation was made by Dubale *et.al.*, (2014) who recorded different storage fungi such as *A. flavus, A. niger, and penicillin chrysogenum cladosporioides* under 6 months of storage period in low land and middle land of the *gombisa* in Kersa and OmoNada of midland ago-ecology and Sekoru of low land agro-ecology. The optimum temperature for the growth of *Aspergillus* spp., *A. flavus, Botrydiplodia the obromae* found to be 30°C, but severe infection of commodities occurred at 35°C. The growth of the pathogen either inhibited or markedly retarded at low temperatures. However, the normal growth resumed when the infected commodities placed at ambient temperatures.

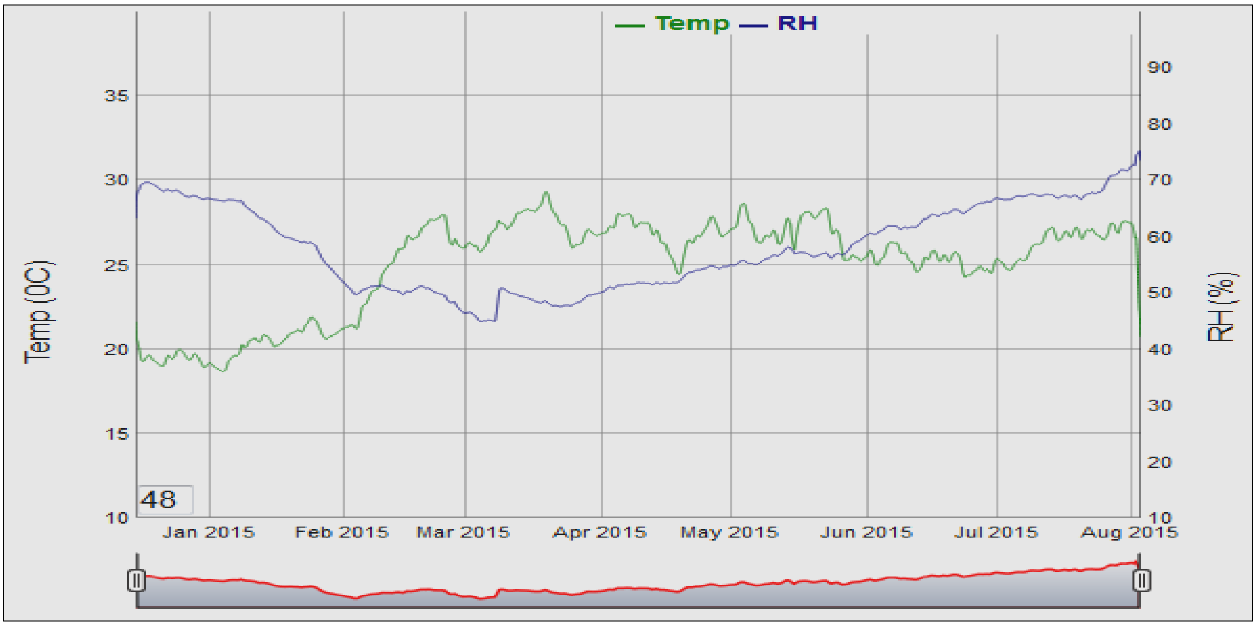


Figure 13. Temperature and relative humidity inside collectors' maize storage system at lowland agro-ecological setting

Where, Temp = temperature in ^{0}C, RH= relative humidity in percentage and 48 role period.

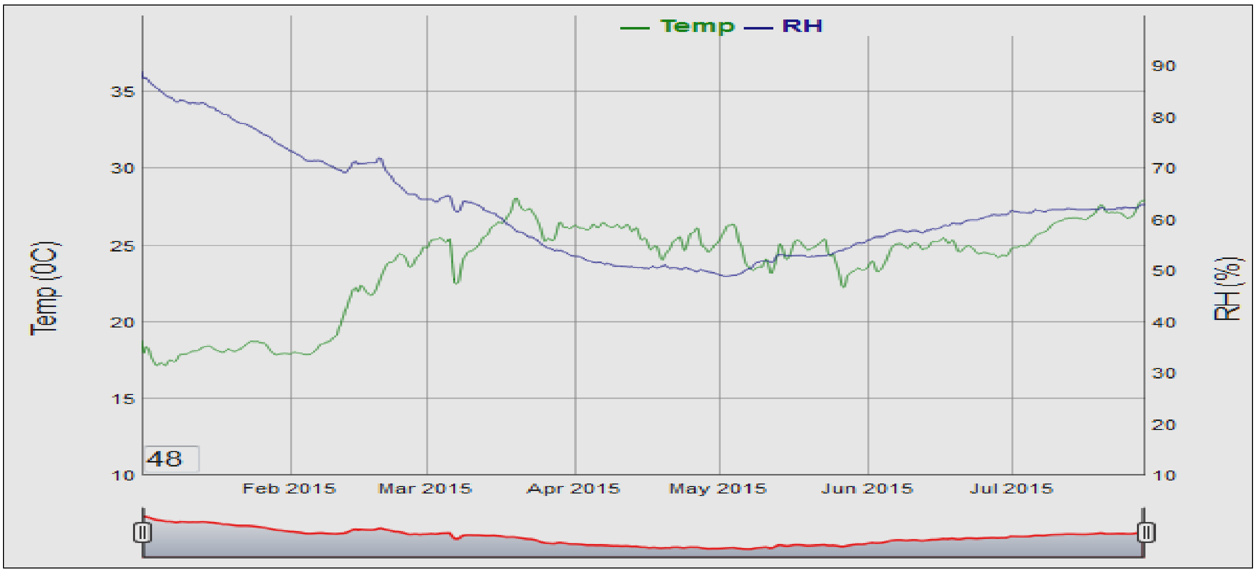


Figure 14.Temperature and relative humidity trend inside collectors' maize storage system at midland agro-ecological setting

Where, Temp = temperature in ^{0}C, RH= relative humidity in and 48 role period

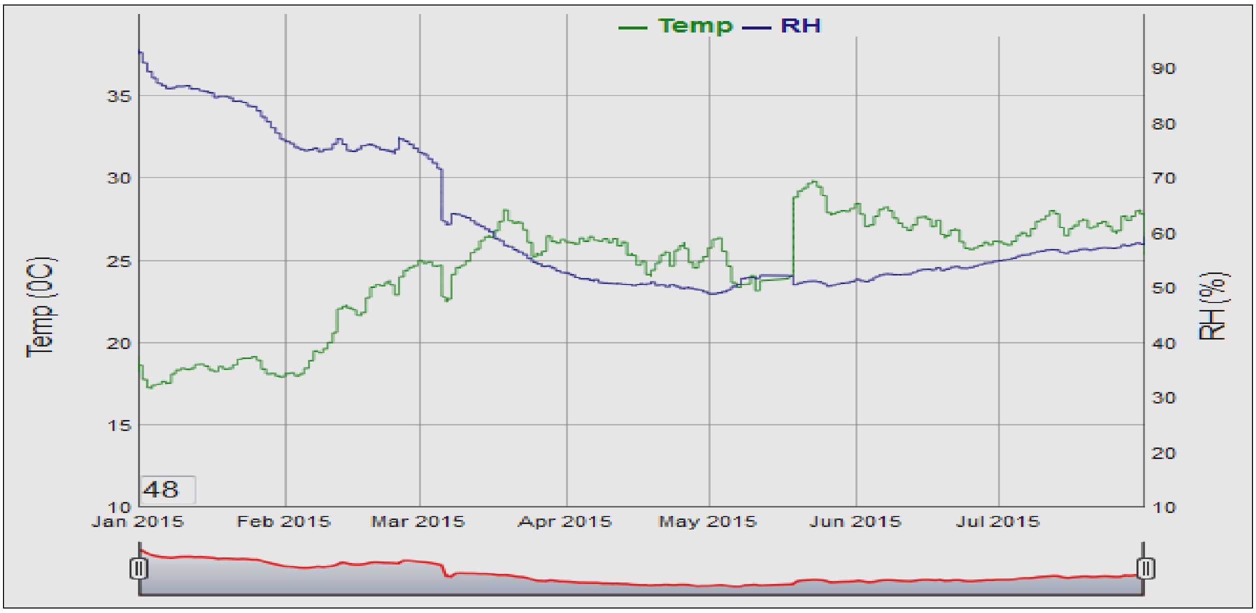


Figure 15. Temperature and relative humidity trend inside collectors' storage maize systems at highland agro-ecological setting.

Where, Temp = temperature in ^{0}C, RH= relative humidity in percentage and 48 role period.

4.2.2.3. Temperature and relatives humidity grain inside stored maize under wholesaler storage house

Initially the temperature and relative humidity of the grain inside the stored maize under whole seller during the first two months of storage duration was ranged (21-27^{0}C) and (50 up to 54) respectively. During two to four months (March and April) of storage duration temperature and relative humidity inside maize grain stored of whole sellers maize storage systems ranged from (25-27°C) and (53-60%) respectively. The results during four to six months (May and June) the temperature and relative humidity inside wholesaler of maize grain stored was ranged (24 up to 27°C) and (60 up to 65%) recorded respectively (Fig. 16). The study of the condition supported by the findings of Malaker *et.al.,* (2008) who stated fungal occurrence gradually increased in all containers (bamboo dole, earthen pitcher, tin container and polyethylene bag) at 25-30°C and according to Paraginski *et.al.,* (2014) the percentage of grain infected by molds significantly increased in the third month of storage for the maize stored at 15, 25 and 35°C.

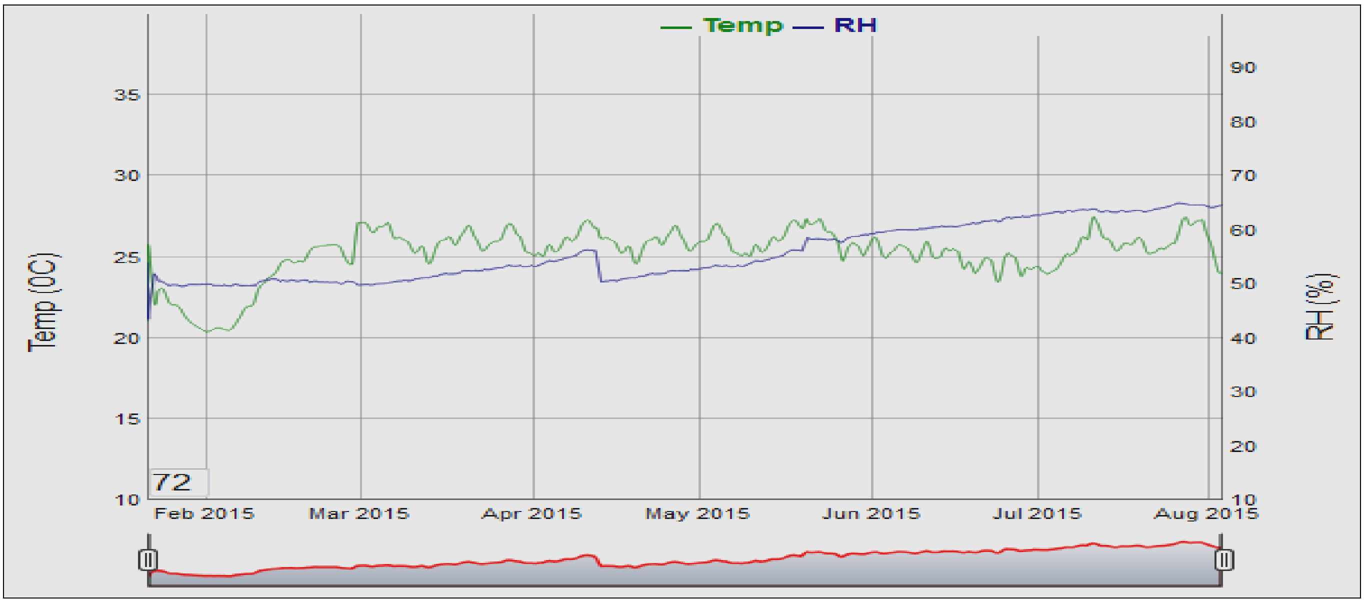


Figure 16. Temperature and relative humidity trend inside wholesalers' maize storage system at Jimma town.

Where, Temp = temperature in ^{0}C, RH= relative humidity in percentage and 72 role period.

4.2.3. Relationship between inside store and ambient temperature and relative humidity

The results of temperature and relative humidity inside maize grain stored in farmers traditional storage with ambient temperature and relative humidity relationship in the study area given in the (Table 18). The results indicated the relationship of temperature and relative humidity inside maize grain stored in farmers traditional storage with ambient temperature and relative humidity at lowland agro-ecology had highly significant($p= 0.000$) and positive correlation. Thus, the relationship between the temperature and relative humidity inside storage and outside storage is positively significant correlated. The change in temperature and relative humidity inside storage affects temperature and relative humidity outside storage and vice versa and there is a direct correlation. Each variables has inverse relationship.

The temperature and relative humidity inside maize grain stored in collector storage system with ambient temperature and relative humidity at lowland agro-ecology had non-significant and positive correlation. This indicates the observed value of the temperature and relative humidity outside storage has no a considerable adverse effect on inside temperature and relative humidity of stored maize grain of collector storage systems. The condition of temperature and relative humidity of inside and outside farmer traditional storage at midland agro-ecology had significant ($p<0.05$) and non-significant ($p>0.05$) respectively and positive correlation was observed. In collector storage system at midland agro-ecology non-significant (*$p>0.05$*) result was observed of temperature and relative humidity and temperature had positively correlated while relative humidity was negatively correlated within inside and outside of the variables. Temperature and relative humidity of maize grain stored inside, outside farmer traditional storage at highland agro-ecology had significant and positive correlation were observed while in collector storage system at highland agro-ecology was non-significant, temperature was positively correlated, and relative humidity was negatively correlated between inside and outside. While at whole seller storage, systems of temperature and relative humidity of maize grain stored inside and outside indicated non-significant and significant respectively with positively correlated.

Generally, there were a significant relationship between ambient temperature and temperature inside maize grain stored in farmers' traditional storage at midland and highland agro-ecology while at lowland agro-ecology highly significant relationship observed between ambient temperature and temperature inside maize grain stored in farmers' traditional storage. Nevertheless, there was a non-significant relationship was observed between ambient temperature and temperature inside maize grain stored in collectors and whole sellers storage systems at lowland, midland and highland agro-ecology. This indicates the observed value of ambient temperature has no a considerable adverse effect on maize grain stored in collectors and whole sellers storage systems at lowland, midland and highland agro-ecology but the ambient temperature has a considerable adverse effect on maize grain stored inside farmers traditional storage at lowland, midland and highland agro-ecology. The study of the condition showed there were highly significant and significant relationships between outside relative humidity and inside relative humidity of maize grain stored in farmers' traditional storage at lowland and highland agro-ecology respectively but non-significant results observed at midland agro-ecology. The relative humidity results indicated non-significant relationship observed between outside relative humidity and inside relative humidity in maize grain stored in collectors' storage systems at lowland, midland and highland agro-ecology.

The fluctuation in environmental conditions changes the temperature and humidity inside the *gombisa* of farmers' traditional storage and may provide favorable conditions for the production of insect, mould and other microorganisms, which deteriorate grain quality during storage. It is therefore the storage *gombisa* environment depends upon the environmental conditions outside the *gombisa* storage. The results of the present study indicated that storage types, storage time, geographic locations and their interaction exhibited a significant effect on the temperature of stored grain. According to (Alabadan and Oyewo, 2005) the temperature and relative humidity percentage of surrounding had a maximum influence on the temperature and relative humidity inside storage and affects the quality of grains. The studies of the condition agree with the results of Sawant, *et.al.*, (2012) who stated that the change in the grain temperature outside the Godown storage changes the grain temperature inside storage and lower than ambient temperature during the first two months storage duration. However, for the next four months, the grain temperature was slightly higher than the ambient temperature due to rainy season started which might result in higher insect infestation. According to Ilelejia *et.al.*, (2007) the temperature starts from 18-35^{0}C, favorable for pests. In relation to this, views the present study of temperature and relative humidity recorded in both storage structure and agro-ecology were optimum for the growth of fungi. Abba and Lovato, (1999) suggested that grains be stored at 20^{0}C, temperature, 40 to 50% relative humidity and 11.5% moisture content.

The results of the present study also consistent with the report of Shakeel *et.al.*, (2014), which indicated grain temperature, insect infestation, aflatoxins, in different storage structures across storage time and agro-ecology showed significant differences. According to Shakeel *et.al.*, (2014), among the storage structures, room structures grain storage had maximum (36.08^{0}C,) grain temperature, Insect infestation and aflatoxins content than compared to earthen bin(It is usually circular in shape and made of clay mixed with straw as the binding material to provide strength) grain storage. Grain storage structures have a great influence on the quality of the stored produce. The level of insect-pest infestation, damages or losses and overall quality of the stored produce over a period depends on the kind of storage structure used. This observation agrees with the findings of Shakeel *et.al.*, (2014), who stated that interactive effect of agro-ecology and storage structure had significant effect on grain temperature, moisture content, aflatoxins, test weight, and germination capacity of the grain. From the storage structure, room type storage had maximum temperature than *gombisa* of farmers traditional storage system across agro ecology and may favor’s fungal species in storage. The results of this study supported by the findings of Chattha *et.al.*, (2016) who observed maximum fungal attack on a room type structure recorded due to high temperature and moisture conditions of room structure storage.

Table 18. Person's correlation for temperature and relative humidity comparing inside the maize store with the ambient condition for maize stored under different actor storage condition

Agro-ecology/ Town	Actor	Temperature		relative humidity	
		r-value	p-value	r-value	p-value
Lowland	Farmer	0.974	0.000	0.955	0.000
	Collector	0.180	0.699	0.293	0.524
Midland	Farmer	0.847	0.008	0.683	0.062
	Collector	0.187	0.693	-0.363	0.377
Highland	Farmer	0.686	0.041	0.728	0.026
	Collector	0.084	0.858	-0.584	0.169
Jimma town	Wholesaler	0.596	0.158	0.920	0.003

4.3. Post-Harvest Loss Implication for Natural Resources Management

The agriculture sector in Ethiopia plays pivotal roles in economic growth, poverty alleviation, employment creation, foreign exchange earnings and food security. However, because of various factors it is becoming increasingly difficult to meet the food requirements of the growing population (Jon, 2007; Abera, 2011 and UNDP, 2013). According to the FAO, food production will need to grow by 70% to feed world population, which will reach 9 billion by 2050, (FAO, 2011). FAO, (2013), stated that meeting the increased global demand in 2050 would be achievable with modern agricultural land increases and significant yield increases. To achieve this goal certain regions will have trouble in natural resources (forest areas) in achieving higher food production. In other way one of the significant contributors for its deprived performance is the low productivity of the sector in general and cereal production loss in particular over the past years (Alemayehu, 2009; Alemayehu *et.al.,* (2012). Such low productivity and post -harvest loss leads to increasing poverty and food insecurity of rural poor farm households in the country. This is due to different risk factors adversely affects maize yield. From this factors Weather risks, low level of crop management practices, pest and diseases, and post-harvest crop losses are the major challenges for farmers in Ethiopia (ECEA, 2009). This condition has impacts on natural resources of the area. There is a need for an integrated and innovative approach to the global effort of ensuring sustainable food production and consumption (FAO, 2010; IFAD, WFP and FAO, 2012).

5. CONCLUSION

From the findings, it is possible to understand a different altitude of the area has their own character on the variables collected over farming systems. It is evident that majority of the respondent were leads their livelihoods by agriculture and majority of the respondents were in productive age category. Agro-ecology of the three-study area has their own value about land allocation to different crops. Majority of agricultural activity in the study area was mixed agriculture, which were integrated crops (annual and perennial) production with livestock husbandry and practiced mixed cropping and sole cropping farming systems. There were practices of managing trees in and around farmland. The practices of managing trees in and around farmland in the study area characterize by scatter, dense and boundary vegetation. The results of the study indicated that, farming systems in the study area are not homogeneity, which is difficult to intervene in adoption of new technology through heterogeneity of farming systems. So the present study considered as the base for other researchers who paying attention to study on issues related with farming systems characterization.

In the study, area with its varied agro-climatic conditions produces a variety of food crops throughout the year. Un-favorable environmental condition during postharvest handling of the crops were responsible for producing fungi species. In the extent of temperature and relative humidity inside farmer traditional storage structure was low compare to ambient temperature and varies with geographic location. These storage structure methods are in adequate for protecting stored maize from ambient temperature. These investigations proved that maize grain stored temperature and relative humidity of farmer and trader storage in lowland, midland and highland makes suitable conditions for fungi species to flourish depending on agro-ecology during the six months of storing.

The study result indicated initial moisture content of the stored product was not in the range safe moisture content in all agro-ecology and storage materials. Grains stored in storage containers lost moisture as storage time increased to 60 days and the values was in the range of save moisture content in all agro ecology. This is due to agro-ecology of the area and temperature and relative humidity fluctuation (up and down) between inside and outside of the storage with environmental climate. Generally, the study findings indicated as different agro-ecology and different storage structure and actors has their own character in susceptible grain stored to different deterioration. So that scientific knowledge is concerned so that preventing grains from deterioration.

6. RECOMMENDATION

- Farming systems often taken as important entry point for scaling up of agricultural technologies. Based on secondary and primary data of this study should cluster and map the major farming systems and subsystems in the study area. Therefore, it believed scaling up of proven technologies within a farming system can substantially enhance crop yield and improve livelihood.
- Maize farmers were using indigenous storage practices such as baskets(*gombisa*) and Sacks which expose to different fungal pathogens species due to expose to ambient temperature and relative humidity. Therefore, they should be adopting new storage technology in order to protect and manage the crops in storage to store for a long time and keep quality.
- Proper monitoring of initial moisture during harvesting and loading stage is very vital content (below14%) to reduce favorability for some fungi species and to make longer it can be stored without infected by mold.
- There should be improved agricultural storage management practices like those that aeration should make when the temperature of the inside is high.
- Check stored grain on a regular basis and aerate as needed to maintain low moisture and proper temperature/aerate grain to safe and equalized temperatures through the grain mass

7. REFERENCES

Addisu Abera, M. Solomon, A. Solomon, D. Fantahun, 2012. Characterization of the Farming and Livestock Production Systems and Potential of Feed-based Interventions in Adama and ArsiNegele Districts, Ethiopia. EIAR, DebreZeit Agricultural Research Center, Ethiopia

Abebe HG and H Bekele, 2006. Farmers' Post-harvest grain management choices under liquidity constraints and impending risks, Implications for achieving food security objectives in Ethiopia. Poster Paper Presented at International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-8. 2006

ACDI/VOCA (Agricultural Cooperative Development International and Volunteers in Overseas Cooperative Assistance), 2003. Staple crops storage handbook; USAID-East Africa,[http://www.acdivoca.org/site/Lookup/StorageHandbook/$file/StorageHandbook.pdf](Accessed December 2016)

Addo, S., Birkinshaw, L.A., Hodges, R.J., 2002. Ten years after the arrival in Ghana of larger grain borer: farmers' responses and adoption of IPM strategies. Int. J. Pest Manag48, 315e325

Adger, W.N., and Kelly, P. M., 1999. Social vulnerability to climate change and the architecture of entitlements, Mitigation and adaptation strategies for global change, 4(3-4): 253-266

Adger, W. N., and Vincent, K., 2005. Uncertainty in Adaptive Capacity, C R Geo science, 337, 399 – 410

Alborch L., M. R. Bragulat, M. L. Abarca, and F. J., Cabañes, 2011. Effect of water activity, temperature and incubation time on growth and ochratoxin A production by Aspergillus niger and Aspergilluscarbonarius on maize grain. *International Journal of Food Microbiology*147 (1): 53–57.

Alemayehu S, 2009. Cereal Production in Ethiopia: Recent Trends and Sources of Growth: International Food Policy Research Institute, Mimeo, Addis Ababa, Ethiopia

Alemayehu S, Dorosh P., Sinafikeh A., 2012. Crop production in Ethiopia: Regional Patterns and Trends Ethiopia in Food and Agriculture in Ethiopia: Progress and Policy challenges edited by Dorosh, P. and Rashid, S. University of Pennsylvania: Philadelphia

Alemu Lelago, Tekalign Mamo, Wassie Haile1, Hailu Shiferaw, 2016. Characterization of Farming Systems in Kedida, Gamela, KachaBira and DamboyaWoredas (Administrative Districts)

Ali, R.H, M. Mahdi, R. B Ali and S. Hojjatollah, 2007. Mycoflora of maize harvested from Iran and imported maize. *Pakistan Journal of Biological Sciences,*10(24): 4432-4437. American Journal of Applied Sciences, 10 (2): 159-163, 2013 ISSN: 1546-9239 ©2013

Andersen E., 2009. Regional Typologies of Farming Systems Contexts, seamless Integrated Project, Eu 6th Frame work Programme.

Arnold, J., Dewees P., 1995. Tree Management in Farmer Strategies: Response to Agricultural IntensificationOxford; Oxford University Press

Barney, R. J., B. D. Price, J. D., Sedlacek, and M. Siddiqui, 1995. Fungal species composition and abundance on stored corn as influenced by several management practices and maize weevil. (Coleoptera: Curculionidae).*Crop Protection* 14(2): 159-164.

Bedada, Begna, Mesayyami and Ishetu Lemma, 2014. Characterization of barley- based farming system in the Arsi Highlands, Ethiopia.

Boserup, Ester, 1970. Woman's role in economic development, London: George Allen &Unwin. *Reprinted as:* Boserup, Ester (2007; Woman’s role in economic development. London Sterling, Virginia: Earthscan *ISBN* *9781844073924*

Bozeman B, 2000. Technology transfer and public policy: a review of research and theory, Res Policy 29:627–655

Brennan JM, Fagan B, Van Maanen A, Cooke BM and Doohan FM, 2003. Studies on *in vitro* growth and pathogenicity of *Fusarium* fungi, European Journal of Plant Pathology 109: 577–587

Brew baker, J. L., 2003. Corn production in the tropics. The Hawaii experience, collage of tropical agriculture andhuman resources university of Hawaii at Manoa,[http://www.ctahr.hawaii.edu/oc/freepubs/pdf/corn2003] (accessed October 2016) Southern Ethiopia

Brinkman, R., 2001. ‘Development in the Moist Savanna Zone of West Africa, Case study for: Dixon, J., Gulliver, A. & Gibbon, D. *Global Farming Systems Study: Challenges and Priorities to 2030.*Consultation Documents, World Bank/FAO, Rome, Italy

Campbell, J. F., F. H. Arthur, and M. A. Mullen, 2004. Insect management in food processing facilities, *Advances in Food and Nutrition Research* 48: 239-295

Charles Woloshuk, 2012. Molds and Mycotoxins in Stored Products, Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Chattha, S.H., Hasfalina, C.M., Mirani, B.N., Mahadi, M.R. and Lee, T.S, 2016. Food grain losses associated with indigenous storage methods and development of storage facilities for food security

Chuck-Hernández, C., S. García-Lara and S. O. Serna-Saldívar, 2012. Conversion into bioethanol of insect (*SitophiluszeamaisMotschulsky*), mold (*Aspergillus flavus* Link) and sprout-damaged maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench), *Journal of Cereal Science* 55(3): 285-292

Coffee Production, Oromia Coffee Cooperative Union websitehttp://oromiacoffeeunion.org/production.htp accessed august 13, 2016.

CSA (Central Statistical Agency), 2007. Agricultural Sample Survey Report on Area and Production of Crops (Private Peasant Holding, Meher Season), Statistica*l* Bulletin, No. 388, Addis Ababa, Ethiopia

CSA (Central Statistical Agency), 2012. Agricultural Sample survey: report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin, (1) Addis Abeba

CSA, 2005. National Statistics, Tables B.3 and B.4(http://www.csa.gov.et/text-file/2005

CSA, 2014. Population projection of Ethiopia for all Regions at wereda level.

CSA, 2013. National Labor Force Survey Report, Addis Ababa, Ethiopia

CSA, 2007. Agricultural sample survey report on area and production of crops (private peasant Holding, Meher season), Statistical Bulletin, No. 388, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency), 2012. Agricultural Sample survey: report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin,(1).Addis Abeba

CSA, 2007. Population and Housing Census of Ethiopia: Results for Oromia Region, Vol. 1, (accessed 13 January 2015)

Datt, G. & Ravallion, M., 1998. 'Why Have some Indian States Done Better than others at Reducing Rural Poverty?' *Economica*65: 17-38

Dawit A, Wilfred M, Nigussie M, Spielman DJ, 2008. The maize seed system in Ethiopia: challenges and opportunities in drought prone areas. Afr. J. Agric. Res. 3 (1):305-314.

DechassaLemessa, "Prosperity Fades: Jimma and Illubabor Zones of Oromia Region", UN-OCHA report November 1999 (accessed 3 April, 2015)).

Dereje Gorfu and Eshetu Ahmed, 2013. Crops and agro-ecological zones of Ethiopia

Dereje Gorfu, 2011. Agro-ecologies of Ethiopia and major crops grown; collaboration with EIAR

Devereau, A. D., R. Myhara and C. Anderson, 2002. Chapter 3: Physical factors in post-harvest quality.*Crop Post-Harvest: Science and Technology: Principles and Practice, Volume 1*.62-92. P.

Devereau, A. D., R. Myhara and C. Anderson, 2002. Chapter 3: Physical factors in post-harvest quality.*Crop Post-Harvest: Science and Technology: Principles and Practice, Volume 1*. 62-92. P.Golob, G. Farrell, J. E. Orchard, eds. Ames, Iowa: Blackwell Science Ltd.

Dharmaputra, O. S., H. K. Purwadaria, H. Susilo, and S. Ambarwati, 1994. The effects of drying and shelling on fusarium spp. infection and fusarium toxins production in maize.*Grain drying in Asia: Proceedings of an international conference held at the FAO regional office for Asia and the Pacific,* Bangkok, Thailand,17-20 October 1995.

Dillon, J., Plucknett, D. &Vallaeys, G., 1978. *TAC Review of Farming Systems Research at the International Agricultural Research Centres*, FAO, Rome

Dixon J., Gulliver A., and D Gibbon., 2001. Farming Systems and Poverty: Improving Farmers' livelihoods in a Changing World.FAO and World Bank, Rome and Washington DC.

Doss, C., Raney, T., Anríquez, G., Croppenstedt, A., Gerosa, S., Lowde, S., Matuscke, I. 2011. The role of women in agriculture. *Food and Agriculture Organization of the United NAtions,* (11), 1–48. Retrieved from http://www.fao.org/docrep/013/am307e/am307e00.pdf

Egal, S., A. Hounsa, Y. Y. Gong, P. C. Turner, C. P. Wild, A. J. Hall, K. Hell, and K. F.Card well. 2005. Dietary exposure to aflatoxin from maize and groundnut in young children from Benin and Togo, West Africa.*International Journal of Food Microbiology* 104(2): 215– 224.

Ekechukwua, O. V., and B. Norton.1999; Review of solar-energy drying systems II: an overview of solar drying technology. *Energy Conversion and Management* 40(6): 615-655.

Ephrem Tesema, 2013. Zonal Diagnosis and Intervention Plan Report for Jimma Zone

Ethiopian Commodity Exchange Authority (ECEA), (2009). Understanding maize, A review of supply and marketing issues, Addis Ababa, Ethiopia.

Fandohan, P., K. Hell, W. F. O. Marasas, and M. J. Wingfield, 2003. Infection of maize by Fusarium species and contamination with fumonisin in Africa.*African Journal of Biotechnology*2(15): 570-579.

FAO, 200. Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. FAO & World Bank, Rome, Italy & Washington, DC, USA.

FAO 2009. Ethiopia: Agriculture and environment or Rome. http://www.fao.org/ag/AGP/AGPC/doc/ Counprof.htm. Accessed on 12/10/2015

FAO, 2011. FAOSTAT online database, available at link http://faostat.fao.org/.Accessed on December 2015.

FAO, 2011. World Agricultural Production. [Online]Available at: http://faostat.fao.org/default.aspx.Accessed 14 April. 2015

FAO, 2011. Global food losses and waste: Extent, Causes and Prevention

FAO, 2013. Food security and sustainable resource use - what are the resource challenges to food security?- A Report for the Food Security Futures conference, 11- 12 April 2013, Dublin, Ireland Frank Place (ICRAF) and Alexandre Meybeck, (FAO)

Fischer, G., Shah, M., and Van Velthuizen, H., 2002.Climate change and agricultural vulnerability

G.H.C.M. Hettiarachchi, JaanakaGooneratne and W.K Hirimburegama, 2001. Effects of initial moisture content and relative humidity on the accumulation of aflatoxin in maize grain during storage.

Gafsi, M., 2006. Cahiers Agricultures. Volume 15, Numéro 6, 491-7, November–December 2006, Synthase Écolenationale de formation agronomique, Unitémixte de recherche (UMR) « Dynamiquesrurales », BP 22687, 2, route de Narbonne, 31326 Castanet Tolosan

Galati.S, Giannuzzi .L and Giner S.A., 2011. Modelling the effect of temperature and water activity on the growth of Aspergillus parasiticus on irradiated Argentinian flint maize. Journal of Stored Products Research **47**: 1-7.

Girma T. Kassie1, Olaf Erenstein, Wilfred Mwangi, Roberto La Rovere, Peter Setimela1, and AugustineLangyintuo, 2012. Characterization of Maize Production in Southern Africa: Synthesis of CIMMYT/DTMA Household Level Farming System Surveys in Angola, Malawi, Mozambique, Zambia and Zimbabwe

Gonzales, H. B., P. R. Armstrong, and R. G. Maghirang., 2009. Simultaneous monitoring of stored grain with relative humidity, temperature, and carbon dioxide sensors.*Applied Engineering in Agriculture* 25(4): 595-604.

Hellevang, K. J., 2005. Natural Air-low temperature crop drying.North Dakota State University (NDSU) extension service. Extension bulletin 35 (revised).Available at:www.ag.ndsu.edu/graindrying/documents/eb35.pdf.2012

http://oromiacoffeeunion.org/production.htp) (accessed august 13 2016).

http://oromiagov.org/socioeconomicprofile/Djimmazone)(http://oromiacoffeeunion.org/production.htp) (accessed august 13 2016).

http://www.csa.gov.et/surveys/population & housingcensus1994/survey0/data/docs/report

http://www.csa.gov.et/surveys/population & housingcensus1994/survey0/data/docs/report

http://www.csa.gov.et/surveys/population&housingcensus1994/)(accessed aug13 2016)

http://www.csa.gov.et/text-file/2005(accessed august 13 2016)

http://www.indexmundi.com/g/r.aspx?c=et&v=39).

Ibtisam Mohammed Ababutain, 2013. Effect of some ecological factors on thegrowth of *Aspergillus niger*and*Cladosporiumsphaerospermum*

International Food Policy Research Institute (IFPRI)., 2007. Policies to promote cereal intensification in Ethiopia: A Review of Evidence and Experience. IFPRI Discussion paper 00707

IPCC, 2007. New Assessment Methods and the Characterization of Future Conditions: In Climate change 2007: Impacts, adaptation and vulnerability, pp: 976.Contribution of working group II to the fourth assessment report of the Intergovernmental panel on climate change.

Jayas, D. S., and N. D. G. White, 2003. Storage and drying of grain in Canada: low cost approaches. *Food Control* 14(4): 255–261.

Jelle Hayma, 2003. The storage of tropical agricultural products

Jian, F., and D. S. Jayas, 2012. The ecosystem approach to grain storage. *Agricultural Research*1(2): 148-156.

Jon P, 2007. The Adoption and Productivity of Modern Agricultural Technologies in the Ethiopian Highlands: A Cross-Sectional Analysis of Maize Production in the West Gojam Zone, University of Susse

Kaaya, A. N., and W. Kyamuhangire, 2006. The effect of storage time and agro-ecological zone on mold incidence and aflatoxin contamination of maize from traders in Uganda.*International Journal of Food Microbiology* 110(3)

Kassie, G. T., O. Erenstein, W. Mwangi, R. La Rovere, P. Setimela, and A. Langyintuo, 2012. Characterization of Maize Production in Southern Africa: Synthesis of CIMMYT/ DTMA Household Level Farming System Surveys in Angola, Malawi, Mozambique, Zambia and Zimbabwe.Socio-Economic Program Working Paper 4.Mexico, D.

Kemeru D. 2007. Farm Level Survey on Farm Tools and Implements in Jimma and Illubabor Zones, Agricultural mechanization for productivity and sustainable use of the natural resource. Proceedings of the first agricultural mechanization post harvest and food science research completed research forum, 5-7 June, 2007. Addis Ababa, Ethiopia. Pp 171-180.

Kifle, D., 2013. Gender role in Agricultural Production in Some Parts of Ethiopia: A Brief Review. *International Journal of Research in Applied Natural and Social Sciences*, *1*(2), 49–52.

Kindt, R., Coe R., 2005. Tree Diversity Analysis.A Manual and Software for Some Common Statistical Methods for Biodiversity and Ecological Analysis. World Agroforestry Center (ICRAF), Nairobi.

Lawrence, M. G., 2005. The relationship between relative humidity and the dew point temperature in moist air a simple conversion and applications.*Bulletin of the American Meteorological Society* 86: 225-233.

Maier, D., E. W. H. Adams, J. E. Throne, and L. J. Mason.,1996. Temperature management of the maize weevil, *SitophiluszeamaisMotsch.*(*Coleoptera: Curculionidae*), in three locations in the United States.*Journal of Stored Products Research* 32(3): 255–273.

MakanFofana, T. Abdoulaye, N. Coulibaly, D. Sanogo, and A. Langyintuo, 2010. Characterization of Maize Producing Households in the Dry Savanna of Mali.

Malaker, P.K., Mian, I.H., Bhuiyan, R.K., Akanda, A.M. and Reza, M.M,. 2008. Effect of storage containers and time on seed quality of wheat; Bangladesh Journal of Agricultural Research 33: 469- 477

Manoch, L., C. Chana, S. Sangchote, and R. Banjoedchoedchu, 1988. Some mycotoxin fungi from agricultural products and food stuff in Thailand. *Proceedings of the Japanese Association of Macro sociology* 1: 45-46.

Marín, S., N. E. Companys, V. Sanchis, A. J. Ramos, and N. Magan, 1998. Effect of water activity and temperature on competing abilities of common maize fungi.*Mycological Research*120(8): 959-964

Mellor, J., 2000. *Agricultural Growth, Rural Employment and Poverty Reduction – Non-Tradables, Public Expenditure and Balanced Growth*. World Bank Rural Week 2000, World Bank, Washington, D.C., USA

Miller, J. D. 1995. Fungi and mycotoxins in grain: Implications for stored product research. A review.*Journal of Stored Products Research* 31(1):1–16

Ministry of Agriculture, 2011. Crop variety register issue number 14. Seyoum Bediye and Zinash Sileshi. 1989. The composition of Ethiopian feeds. Research Report No. 6. IAR, Addis Ababa, Ethiopia.

Mirna VOLENIK, Vlatka ROZMAN, Irma KALINOVIC, Anita LISKA, Darko KIŠ, Branimir ŠIMIĆ, 2006. Influence of Relative Humidity and Temperature on the Changes in Grain Moisture in Stored Soybean and Maize

Montross, J. E., M. D. Montross, and F. W. Bakker-Arkema., 1999. Part 1.4 Grain storage 46-59.F. W. Bakker-Arkema, D. P. Amirante, M. Ruiz-Altisent, and C. J. Studman, eds. *CIGR Hand Book of Agricultural Engineering.VolumeIV.Agro-Processing Engineering.*St. Joseph, Michigan, USA

MosisaWorku, Jemale Abdurrahman, Leta Tulu, Haji Tuna, Legesse Wolde, Kassa Yihun, Wonde Abera, Aschalew Guta, Sewagegne Tarikue, Teshale Asefa, Tamirat Birhanu, Yosef Beyene and Habtamu Zeleke., 2001. Development of improved maize germplasm for the mid and low altitude sub humid agro ecologies of Ethiopia. In: Enhancing the Contribution. Of Maize to Food Security in Ethiopia: Proceedings of the Second National Maize Workshop.

Moturi, W. K. N., 2008. Factors likely to enhance mycotoxin introduction into the human diet through maize in Kenya.*Africa Journal of Food Nutrition and Development* 8(3): 265-277.

NBE, 2013. Annual Report, Addis Ababa, Ethiopia

Narayanasamy .P., 2006. Postharvest pathogens and disease management.John Wiley and Sons, Inc. publication. New Jersey. 563p.

Nukenine, E.N., 2010. Stored product protection in Africa: Past, present and future. *Julius-Kühn-Archiv*425: S-26.

Obanyi, S.N., E. M. Muya, M. Nqutu, and H. Bulle, 2012. Characterization of farming systems in mountain and oasis areas of northern Kenya: constraints and opportunities KARI-National Agricultural Research Laboratories, Box 14733-00800, Nairobi, Kenya

Oumer, S., 2011. On–farm phenotypic characterization of cattle in Jimma zone, south western Ethiopia.

Oyekale, K. O., I. O. Daniel, M. O. Ajala, and L. O. Sanni., 2012. Potential longevity of maize seeds under storage in humid tropical seed stores. *Nature and Science* 10(8): 114-124.

Paraginski, R.T., Vanier, N.L., Berrios, J.D.J., Oliveira, M. and Elias, M.C., 2014. Physicochemical and pasting properties of maize as affected by storage temperature; Journal of Stored Products Research 59:209- 214

Population and Housing Census of Ethiopia: Results for Oromia Region, 2007. Vol. 1, Tables 2.1, 2.5, 3.4 (accessed august 13 2016) http://www.csa.gov.et/index.php?option*Population and Housing Census of Ethiopia: Results for Oromia Region,* 1994 Vol. 1, part 1,(accessed august 13 2016)

Reed, C., S. Doyungan, B. Ioerger, and A. Getchel., 2007. Response of storage molds to different initial moisture contents of maize (corn) stored at 25°C, and effect on respiration rate and nutrient composition. *Journal of Stored Products Research* 43(4): 443–458.

Rees, D., 2004. *Insects of Stored Products.*Melbourne, Victoria: CSIRO Publishing Regional Agricultural Trade Expansion Support Program (RATES).2003. Maize Market Assessment and Baseline Study for Ethiopia.

Regional Agricultural Trade Expansion Support Program (RATES)., 2003. Maize Market Assessment and Baseline Study for Ethiopia.

Rehman, Z. U., F. Habib, and S. I. Zafar., 2002. Nutritional changes in maize (*Zea mays*) during storage at three temperatures. *Food Chemistry* 77(2):197–201.

Samuel, A., A. Saburi, O. E. Usanga, I. Ikotun, and I. U. Isong, 2011. Post–harvest food losses reduction in maize production in Nigeria.*African Journal of Agricultural Research* 6(21): 4833-4839.

Sanchis, V., I. Viñas, M. Jimenez, M. A. Calvo, and E. Hernandez, 1982. Mycotoxin-producing fungi isolated from bin-stored corn. *Micropathological*80(2): 89-93

Shakeel Hussain Chattha, TeangShui Lee, Benish Nawaz Mirani, Che Man Hasfalina, 2014. Effects of storage methods, storage duration and different geographical locations on quality of stored wheat (Triticumaestivum) in sindh, Pakistan

Shah, W. H., Rehman, Z. U., Kausar, T. &Hussain, A., 2002. “Storage of wheat with ears”. Pakistan Journal of Science and Industrial Research 17(3): 206–209.

Singh, J., 1987. Field manual of breeding procedure. FAO, Rome *Socio-economic profile of the Djimma (sic) Zone* Government of Oromia Region (accessed august 13 2016). http://oromiagov.org/socioeconomic profile/Djimma zone

Solomon, O., 2008. Small scale oil palm farmers perception of organic agriculture in Imo State, Nigeria,Journal of Environmental Extension . 7: 67-71

Sone, J., 2001. Mold growth in maize storage as affected by compound factors: Different levels of maize weevils, broken corn and foreign materials, and moisture contents. *Journal of Asia-Pacific Entomology* 4(1): 17-21Storage Handbook/$file/Storage Handbook. Pdf Accessed November 2015

Teklu Erkossa, Seleshi Bekele And Fisum Hagos, 2009. characterization and productivity assessment of the farming systems in the upper part of the nile basin., International Water management Institute, P.O. Box 5689, Addis Ababa, Ethiopia

Tesfaye Abebe, 2005. Diversity in Homegarden Agroforestry Systems of Southern Ethiopia.PhD Thesis, Wageningen University and Research Centre, the Nether lands.

Tesfaye, M., 2007. Characterization of cattle milk and meat production, processing and marketing system in Metema district, Ethiopia

TeshagerAyalew, Belay Duguma and Taye Tolemariam, 2013. Socioeconomicand Farm Characteristics of Smallholder Cattle Producers in Ilu Aba Bora Zone of Oromia Regional State, South Western Ethiopia

Tsedeke, K., 2007. Production and marketing systems of sheep and goat in Alaba, southern Ethiopia.

Tsutomu TAKANE, 2008. labor use in smallholder agriculture in Malawi: six village case studies, labor use in smallholder agriculture in Malawi: six village case studies

Tuite, J., and G. H. Foster., 1979. Control of storage diseases of grain. *Annual Review of Phytopathology*17(1): 343-366.

UNDP (United Nation Development Program), 2013. Towards Building Resillence and supporting transformation in Ethiopia, Annual Report, 2013, www.et.undp.org

UNFCC, 2014. UN Framework Convention on CC. Archived 2 August 2015

USDA (United States Department of Agriculture), 2012. Grain world markets and trade United States department of agriculture foreign agricultural service. Circular series. FG 09-12. September 2015. Available at: http://www.fas.usda.gov/psdonline/circulars/grain.pdfAccessedOctober 2015.

USDA United States Department of Agriculture, 2007. World maize production.com

websitehttp://oromiacoffeeunion.org/production.htp accessed august 13 2016

Wesel A, Peng, 2009. Agro-ecology as a science, a movement and a practice.A review. Agronomy for Sustainable Development 29, 503-515

wikipedia.org/wiki/ Oromia Coffee Oromia Coffee Cooperative Union website acceesed February 2015

wikipedia.org/wiki/Socio economic profile of Jimma zone, accessed February 2015

Williams, R. J., and D. Macdonald., 1983. Grain molds in the tropics: Problems and importance. Annual *Reviews of Phytopathology* 21(1): 153-178.

Wiredu, N.A., K.O. Gyasi, T. Abdoulaye, D. Sanogo, and A. Langyintuo, 2010. Characterization of maize producing households in the Northern Region of Ghana. Country Report – Ghana.: CSRI/SARI – IITA, Ibadan, Nigeria. 24 pp. Printed in Nigeria by IITA

Workneh, A. and J. Rowlands, 2004. Design and execution and analysis of livestock breed survey in Oromia regional state, Ethiopia. OADIS.(Oromia Agricultural Bureau), Addis Ababa, Ethiopia and ILRI (International Livestock Research Institute) Nairobi, Kenya, pp: 260.

World Bank, 2012. Age dependency ratio; young (% of working-age population) in Ethiopia was last measured at 81.19 in 2012, according to the World Bank assessments.

World Bank, FAO, NRI, 2011. Missing Food: The Case of Post-Harvest Grain Losses in Sub-Saharan Africa. In: Economic Sector Work Report No. 60371-AFR. World Bank, Washington, DC.

World Bank, NRI and FAO, 2011. Missing Food: The case of postharvest grain Losses in Sub-saharan Africa, Report No. 60371-AFR

Yakubu, A., C. J. Bern, J. R. Coats, and T. B. Bailey, 2011. Hermetic on-farm storage for maize weevil control in East Africa.

Yisehak K., 2008. Gender responsibility in smallholder mixed crop–livestock production systems of Jimma zone, South West Ethiopia., Livestock Research for Rural Development.Volume 20, Article #11. Retrieved October 31, 2016, from http://www.lrrd.org/lrrd20/1/yise20011.htm

YisehakKechero, Taye Tolemariam and Aynalem Haile, 2013. Characteristics and Determinants of Livestock Production in Jimma Zone/Southwestern Ethiopia