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Addis Ababa University
Addis Ababa
Ethiopia

College of Development Studies
Center for Rural Development

BARLEY TECHNOLOGIES ADOPTION AND ITS CONTRIBUTION TO FARM HOUSEHOLDS' INCOME AND FOOD AVAILABILITY IN SEMENSHEWA ZONE, AMHARA REGION, CENTRAL ETHIOPIA

By

DEREJE HAMZA MUSSA

A Thesis Submitted to Center for Rural Development College of Development Studies, Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Development Studies (Rural Development)

Advisor: Ali Hassan Muhaba (PhD)

August, 2018

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DECLARATION

I the undersigned declare that this PhD dissertation entitled: ***Barley Technologies Adoption and its Contribution to Farm Households' Income and Food Availability in Semen Shewa Zone, Amhara Region, Central Ethiopia*** is conducted by me under the supervision of Ali Hassen Muhaba (PhD); and with special support of Bamlak Alamirew Alemu (PhD) from the Center for Rural Development Studies, College of Development Studies, Addis Ababa University. I further declare that, this dissertation is original work, and it was not submitted to other universities or institutions in the fulfillment for any degree or diploma. All sources of materials used in this dissertation are well acknowledged.

Name	Signature	Date
Dereje Hamza Mussa		28/08/2018
Ali Hassan Muhaba (PhD)		28/08/2018

Addis Ababa University

School of Graduate Schools

This is to certify that the thesis prepared by Dereje Hamza Mussa entitled: ***Barley Technologies Adoption and its Contribution to Farm Households' Income and Food Availability In Semen Shewa Zone, Amhara* Region, Central Ethiopia,** submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Development Studies complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the examining Committee

Name...Ali Hassen...Signature...........Date...29/08/2018
Advisor

Examiners

Name...Degefa Tolossa...Signature...........Date...29/08/2018

Name.......................................Signature........................Date...................

Name...Negussie Semie...Signature...........Date...29/08/2018
Chair person

ACRONYMS

AAU	Addis Ababa University
ADB	African Development Bank
AESE	Agricultural Economics Society of Ethiopia
BBM	Broad Bed Molder
CC	Contingency Coefficient
CDS	College of Development studies (AAU)
CRD	Center for Rural development (AAU)
CSA	Central Statistics Authority
DA	Development Agents
DC	Developing Countries
DHS	Demographic and Health Survey
EAS	Extension and Advisory Services
EEA	Ethiopian Economic Association
EEPRI	Ethiopian Economic Policy Research Institute
EHRD	Ethiopia Humanitarian Requirements Document
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
Ha	Hectare
HHs	Households
HU	Haramaya University
HYV	High Yielding Varity
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ILRI	International Livestock Research Institute
JU	Jimma University
LDCs	Less Developed Countries
masl	meter above sea level
MEDaC	Ministry of Economic Development and Cooperation
MoARD	Ministry of Agriculture and Rural Development
MPP I &II	Minimum Package Programme I and II
NSZADO	North *Shewa* Zone Agricultural Development Office
OSSREA	Organization for Social Science Research in Eastern and Southern Africa
PADEP	Peasant Agricultural Development Extension Project
PADETES	Participatory Demonstration and Training Extension System
SAFE	Sasakawa Africa for Education
SSA	Sub-Saharan Africa
SWZOA	South Wollo Zone Office of Agriculture
T&V	Training and Visit
USAID	United States Agency for International Development
VIF	Variable Inflation Factor
WFP	World Food Program

DEDICATION

This PhD thesis is dedicated to my sister Aleme Hamza Mussa, the mother of (Yirga Hamza, Zenet Abol, Hayat Abol and Seada Abol), who unfortunately passed away during my study by leaving her four children and unforgettable grief on me. It is also dedicated to my father Hamza Mussa, who passed away when I was grade 6 and to my Mother Ayelech Sebsybe, who passed away before the beginning of my PhD study.

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ABSTRACT

In Ethiopia, more than 80% of people are living in rural areas. They directly or indirectly relied on agriculture (mainly on crops and livestock production) for their livelihoods. Crop agriculture includes cereals, pulses, oil crops, vegetables and others. Among cereals, barley is the one widely produced in the highlands of the country for the farm households' food and income. Semen Shewa Zone (Amhara Region) is one of the highland areas of the country where barley is widely produced. Barley in Ethiopia ranks fourth to fifth in area coverage and production among the major cereals that include (teff, wheat, maize, sorghum and barley). In the highlands of Ethiopia in general, and in Semen Shewa Zone, in particular, barley is produced during main rainy season (Meher/Kiremt), during small rainy season (Belg), and using irrigation. It has various purposes and benefits for the farm households that include, its grain for food and income, its straw for livestock feed and for construction and plastering of house walls by mixing it with mud, and its stem for house roofs thatching. It is produced with and without using improved agricultural technologies. However, studies are scarce in identifying the determinants to use/adopt or not to use/not to adopt improved agricultural technologies in barley production and the contributions of adoption in farm households' income and food availability as well as the roles of farmers' perception towards extension service in adoption of improved technologies, in enhancing farm households' income and food availability. As a result, this study was designed and conducted in the selected woredas (Ankober, Basona, and Angollela) of Semen Shewa Zone to fill these knowledge gap and come up with evidence based information that can be used by policy makers, development practitioners and researchers. This study conducted in nine rural kebeles selected from the three selected woredas. For this study, 812 respondents (604 male and 208 female) 36 FGD participants were selected and used for quantitative and qualitative data collection respectively. The econometrics models that include Multivariate probit, ordered and binary logit, Censored Tobit and multiple linear regression models were used in addition to descriptive statistics. The likelihoods of adoption of barley technologies estimation using multivariate probit model showed that frequent plow likelihood adoption was 74%, fertilizer 72%, compost 56%, frequent hand weeding 47%, weedicide 42%, farm land drainage 27% and improved barley seed 20%; and the likelihoods of joint adoption and joint rejection of all technologies by all sample HHs were 5% and 2% respectively. Furthermore, farm land size, food availability status, income status, credit access, extension service, barley selling options, improved livestock, affected fertilizer adoption positively and significantly; while credit center distance, and participation in Belg production were affected negatively and significantly. In addition, the descriptive analysis showed the income and food availability statuses. As a result, out of (812) sample households, 49% were with equal and above (3781 Eth. Birr.) minimum income threshold; and 65.52% were with equal and above (2550Kcal) minimum food availability threshold. Regarding the perception level, 24.14% were with low, 6.53% with medium, and 69.33% were with high perception level towards the importance and roles of agricultural extension service to enhance adoption, barley yield, food availability and income of farm HHs. In FGDs, high cost inputs, poor quality of inputs and high credit interest rate were among the most limiting factors affecting adoption, low income and food availability statuses of HHs.

Keywords: ***Adoption, Barley technologies, Income, Food Availability, Perception***

CHAPTER ONE: INTRODUCTION

1.1. Background of The Study

Agriculture, which was begun before 10,000 years ago, mainly includes the production of plants and animals, and it is critically important for humans (FAO, 2008). It is the world's largest economic sector, on which, about 2.5 billion people rely for their livelihoods. Over 70 percent of the world's poor are living in rural areas, and have engaged in farming (Foster, *et. al.,* 2003; World Bank, 2014). Agriculture plays crucial roles in most economies, especially, in developing countries. It provides food, income and employment; and its growth and productivity improvement is fundamental for the development of other sectors, to achieve food security, to alleviate poverty and to make economic development sustainable (Timmer, 2002; FAO, 2002; FAO, 2005a; World Bank, 2007 and 2008; Diao, et.al, 2006; Bandiera and Rasul, 2010; United Nations, 2014; Sahu and Das, 2015). Agriculture in low-income countries including those in Africa, provides employment for 65% of the labor force; and accounts for 32/% of GDP (World Bank, 2014).

The growth and development of agriculture, which leads to poverty reduction is not possible without using yield-enhancing improved technologies. Without using yield-enhancing technologies, it is not possible to meet the increasing demand of people through area expansion and traditional cultivation (Moyo, *et al*., 2007). According to, Foster and Rosenzweig (2010), improved technologies are viable only, when they are used/adopted by farmers. Adoption and diffusion of improved agricultural technologies are also important and the best way for developing countries to countries to achieve food security, move out of poverty and catch the developed countries. In addition, the ultimate goals of adoption and diffusion of innovations/technologies are to improve the well-being of farming households by improving their production and income (Sandra, *et al.,* 1989). Therefore, in policy making and development interventions, in less developed countries, agricultural growth and its sustainability are the priority issues (FDRE, 2012; FDRE, 2010a; Asfaw and Shiferaw, 2010).

In sub-Sahara Africa, the two thirds of people are engaged in agriculture, and one fourth of them are chronically hungry; although agriculture supports the livelihoods of the majority of the poor; and has the potential to economic growth and poverty reduction through adoption of improved technologies (Kelsey, 2011; Diao, et.al, 2006; FAO, 2008; FAO, 2014a; Dercon and Gollin, 2014). Ethiopia, as one of the less developed and African countries, the majority of its people are relied on agriculture, mainly on crops and livestock production for their livelihoods (Canali and Slaviero, 2010; and CSA 2009). For example, in Ethiopia, agriculture provides employment for more than 85% of the people, and it contributes for 50% exports and for 47% of GDP (FAO, 2010; CSA 2014). However, the sector is characterized by low productivity, low input use, post-harvest loss, population pressure, poor farming practices, and land degradation (Yao, 1996; Rashid, *et al.*, 2010). The national development strategy of Ethiopian agriculture is in line with a view that poverty reduction is not possible without the growth of agricultural yields and that requires adoption of improved agricultural technologies (Samuel, 2006). Furthermore, the Ethiopian agriculture has dominated by smallholders who produce about 90% of total agricultural production, on average with less than one hectare farmland ownership per household (CSA, 2011).

Small-scale cereal crops production is the most important production in Ethiopia. The majority of rural households produce cereals for consumption and income. Cereals production and marketing is the means for the livelihoods of millions of smallholders in Ethiopia (Tigist, 2017). In 2007 main cropping season, 70% of farm land (CSA, 2009); and in 2011 about 73% of crop land used for cereals production. Nearly 70% of smallholders' caloric intake was covered from cereals (CSA, 2011). During 2014 cropping season, from the total cropped area and from grain crops, the cereals' share was around 78% and 86%, respectively (CSA, 2014). Hence, cereals are the dominant staples for the majority of Ethiopians, which provide the daily calorie intake source for 62% of households and for more than 40% of their food expenditures. Furthermore, cereals provide employment for 60% of rural households and contribute 65% for total agricultural GDP. In Ethiopia, cereals covered 80% of total farmland, estimated to be 8.7 million hectares (Tura and Gashaw, 2015).

Cereal agriculture was started with the domestication of barley, and wheat (Morrell and Clegg, 2006; Abimbola and Oluwakemi, 2013). Among cereals, barley (Hordeum vulgare L) was first domesticated in the Fertile Crescent of the Middle East (Smith, 1998; Zohary and Hopf, 2000). Barley domestication and cultivation started, before 10,000 years ago (Lev-Yadun *et al*,. 2000). It is an annual cereal crop, belongs to the tribe Triticeae of family Poaceae (Harlan, 1976; Martin, *et al.*, 2006); and one of the most important crops, cultivated since ancient times for human consumption, animal feed, pharmaceuticals and alcoholic beverages, due to its versatility, ability to adapt unfavorable climate and soil conditions (Arendt and Zanini, 2013; Bantayehu, 2009). Nutritionally, barley is superior among cereals. It is common, popular and the oldest domesticated cereal crop, cultivated in temperate regions, at higher latitudes, and mountains in the tropics (Marlett, 1991).

In Ethiopia, barley was domesticated and cultivated for the past 5000 years (Bayeh and Berhane, in Mulatu and Grando, 2011). Predominantly, it is produced and cultivated in high altitudes (>2000 m.a.s.l) of the country (FAO, 2014). The priority purpose of barley in Ethiopia is for human consumption (Zohary and Hopf, 1993; Harla, 1976; McFarland, *et.al.,*2014; although its worldwide production is mainly for livestock feed and for malt (Zohary and Hopf, 1993; Harla, 1976; McFarland, et.al; 2014). Barley in Ethiopia is the one, among the five major cereal staples, which include teff, wheat, maize, sorghum, barley (Dorosh and Rashid, 2013; CSA, 2009).

Barley ranked fourth in production in *Meher* seasons from 2004/05 to 2007/08 and from 2010/2011 to 2011/2012 (Alemayehu, *et. al.,* 2012). Ethiopia is the second largest producer of barley, in Africa, next to Morocco that accounts for about 25 percent of total barley production in the continent (FAO, 2014). Hence, has been Ethiopia recognized as a center of diversity and barley germplasms, which globally recognized significance for their better traits such as disease resistance (Vavilov, 1951; Qualset, 1975; Bonman et al., 2005). The long history of barley cultivation and the diverse agro-ecological and cultural practices in Ethiopia have resulted in a wide range of barley diversity (Firdissa, et. al., 2010). Although barley yield in Ethiopia is higher than the continent-wide average, its yield remains significantly, lower than the global average (Rashid, et. al., 2015).

In some regions of Ethiopia, barley has produced two times, in two seasons, during *Belg* (small rainy) season, which relies on short rainfall period, from March to April; and during *Meher* (long rainy) season, which relies on the long rainfall period, from June to September (Bekele *et al*. 2005; Lakew, *et al*. 1997). Barley is the most dependable/trusty and desirable crop for resource-poor highland farm households, where poor soil fertility, frost, water logging, soil acidity and soil degradation are the major yield limiting factors, where other cereals fail to grow. It is a cool weather crop grown in the highlands of Ethiopia within (2000 to 3500) masl altitudes and with an optimum rainfall ranging from 500 to 1200 mm (Asresie, *et. al.,* 2015). Barley in Ethiopia is the major source of food, homemade drinks, animal feed and cash (Mulatu and Grando, 2011); its grain is used also in diversity of traditional recipes; and for the preparation of diets that are deeply rooted in the culture and tradition of rural people. Its straw is also used for livestock feed and house wall construction plastering, and its stem is by the farm households' for their houses roof thatching (Firdissa, *et. al.*, 2010).

Barley production has largely been driven by a desire to maximize productivity (Briggs, 1998; Johnson and Janzen, 1999; Mallet, 2014); although, adoption of barley technologies is constrained by different problems (Kinyangi (2014); Chi and Yamada (2002); Diagne and Demont (2007); Koundouri, *et al,* (1985); Feder, *et al.,* (1985); Foster and Rosenzweig (1995); Fafchamps *et al.,* (2005). Barley farmers, in Ethiopia, do not fully adopt barley yield enhancing inputs, such as, fertilizer and improved seeds, because of many limiting factors that include weather variability, financial constraints, awareness problems of farmers about the positive roles of improved agricultural technologies, risk-aversion behavior of farmers, institutional constraints/failures, lack of human and financial capital and infrastructures, high cost of technologies, adverse climatic conditions, in-appropriate land uses, non-business orientation of agriculture, limited/poor/no accesses to and linkages between markets and farms, low value chains and value additions, backwardness of technologies and diminished cultivated land size (CSA, 2014).

The availability of improved agricultural technologies is necessary for innovation/technology adoption that helps to increase agricultural productivity. Technology/innovation adoption is not dependent only on availability of the technology/innovation, but also on economic, policy, and institutional incentives such as credit and agricultural extension service (Dadi, *et al.,* 2004; Halloran and Archer, 2008). Agricultural extension service has the potential to help farmers to increase their production and incomes (Mengistie and Belete, 2015) through appropriate and timely advising of farm households how to use improved agricultural technologies. Important task of agricultural extension is to facilitate exchange and sharing of information, knowledge and skills, as these help farmers to learn more about innovations to improve their agricultural production. Lack of agricultural extension services may result in a knowledge gap to adopt modern technologies (Diao, 2010).

Access to extension services is the key in technology adoption by providing information about the existence, proper and effective application, benefits of new technologies and improved practices (Mwangi and Kariuki, 2015). Adoptions of improved technologies, farming techniques and extension service activities had showed positive relationship and impacts on income, food security and poverty reduction (Wanyama, *et al*., 2010; Solomon et al.,2010; Adekambi, et al., 2009; Setotaw, et. al., 2003). In the study area, *Semen Shewa* Zone, which is located in *Amhara* Region, central Ethiopia, barley is produced widely using and without using improved agricultural technologies and improved farming practices.

Farm households in the study area use/adopt one or more improved technologies and practices in their barley production. However, determinants of adoption of one or more improved barley technologies and practices; the effects of improved barley technologies adoption on farm households' income and food availability; and farm households' perception towards agricultural extension service and its roles in enhancing farm households' income and food availability at household level, in the study area have not been studied. Hence, this study was designed and conducted in *Ankober*, *Badsona* and *Angollela woredas*, in *Semen Shewa* Zone of *Amhara* Region, Central Ethiopia. The result of the is expected to fill the knowledge gaps and to come up with research findings that can be used, by many people and institutions/organizations as inputs by policy makers, development program planners, and practitioners as well as by researchers for further investigations.

1.2. Statement of the problem

Adoption is the integration of a new technology in the existing practices to enhance agricultural production; to adequately supply the basic human need (nutrition); to enhance growth; to overcome poverty and food insecurity (Jain, *et al.,* 2009). Improved input and output can be described as the new technology that can raise output and reduces production cost which in turn results in substantial gains in farm income. Hence, improving the productivity, profitability and sustainability of small-holder farming is the main pathway out of poverty. Three out of four of the poor people in the world lived in rural areas, around 65% of them relied on agriculture and livestock for their livelihood (World Development Report, 2008). Increasing production and productivity of agriculture could address the food shortage by providing more food and by generating employment and income (Veen and Tagel, 2011). Agriculture and its production are the basis for food production, which provides the necessary components to maintain human healthy and active life. Production in agriculture is an indicator for food availability (FAO, 2010).

Globally, smallholder agriculture intensification to increase output, livelihood diversification to raise income, and migration, which is a spatial separation between resident and livelihood activities to which the family/household members engaged, is the strategy in alleviating poverty from the LDCs (Tiffen et al., 1994). Agriculture plays a unique role in poverty reduction through adoption of improved technologies in LDCs that on average, a rise in households' income, because of growth in agriculture, by 2%, leads to a fall in poverty by 4%. In addition, the GDP growth because of agricultural growth is 4 times more effective in reducing poverty than GDP growth in other sectors (Delgado, *et al*, 1999, Ravallion, 2001; Asfaw, *et. al*, 2011; Kassie *et al*, 2011; Asenso-Okyere, 2011; Adofu *et al.*, 2013; Talebpour, *et. al*, 2015). Growth in agriculture is important to improve productivity in LDCs through technology adoption, which leverages to improve farmers' lives (Doss, 2006).

The food supply sources include home/domestic production, food stocks, imports, and food aids (Omonona, *et. al.*, 2007). Sufficient food availability is the basis for social, political, economic development and basic human entitlements (Palacios and Mehta, 2011). Low agricultural productivity in LDCs keeps rural people trapped in vicious poverty circle that caused under nutrition, poor health, poor cognitive development and limited adoption of improved technologies (Gollin, 2010; Johnston and Mellor, 1961). In SSA, agricultural productivity has not yet increased due to low use of technologies and other factors (Shisanya *et al.*, 2009; Pretty, *et al*., 2011). The average farmer in SSA applies eight (8) Kg of fertilizers per (ha) compared to 101 kg in South Asia and over 145 kg in developed countries (Morris, *et al.*, 2007; World Bank, 2010). To improve rural household's livelihoods in developing countries via new technologies remain a mere wish, if adoption is low. Extension helps farmers to aware of and adopt improved technologies from any source to enhance production, income and welfare (Ajayi, *et al*; 2003; Gemeda, *et al.*, 2001; Morris, *et al*., 1999).

Agricultural technologies and their adoption are the means to improve agricultural production, which help to reduce/fight poverty and hanger, to improve food and nutritional security (Morris, *et al*., 2007; Barrett, *et al.*, 2010; and Feder, *et al.*, 1985). Agriculture in Africa is predominantly smallholder farming, which plays a crucial role in food production for both rural and urban populations and remains a major source of income, employment, and export earnings (Krishna, 1977). Farmers adopt multiple agricultural technologies to deal with a multitude of production constraints. Agricultural extension service plays vital role in sharing knowledge, technologies, and agricultural information. The extension service is one of the critical change agents to transform subsistence farming, which is critically important in promoting household food security, wealth and employment creation and poverty reduction. Almost all countries in the world deliver extension service to rural people to improve production and their living standard (Wambura, *et. al*, 2012). Extension is responsible for serving about one billion small-scale farmers in the world (Davis, *et. al.*, 2010); and it is the mechanism to deliver information and technology to farmers (Moris, 1991).

Sub-Saharan Africa is the only region where livelihood and food security deteriorates and the number of people living in poverty has increased due to low adoption, then low agricultural productivity (Norton, *et al.,* 2010). Agricultural growth and adoption remain low in Africa and in (SSA) that lagged behind economic and population growth (Diao, et al., 2012; Spielman, et al., 2010; Briquette, 1999; Bandiera and Rasul, 2006). In Asia, adoption and proper utilization of technologies have resulted in Green Revolution where its replication in African has shown a high promise in increasing productivity. Adoption of improved agricultural technologies is crucial to increase yields, to meet food demand and food security, thereby, to transform the low productivity subsistence agriculture to a high productivity, agro-industrial economy (Becerril and Abdulai 2009; Just and Zilberman, 1988).

Adoption of agricultural technologies and their determinants are the key policy focuses to bring change in agriculture (Aman and Tewodros, 2016). Hence, the deeper understanding of factors that play positive and negative roles in adoption help policy makers and other stakeholders in designing effective strategies. According to Tey and Brindal (2012), factors affecting adoption of improved agricultural technologies include socioeconomic, agro-ecological, institutional, information, farmers' perception and behavior, and technological issues. Some studies classify determinants of adoption of improved agricultural technologies into farmers' characteristics, farm structure, institutional characteristics and managerial structure, while others classify them in to social, economic and physical categories. Others also grouped determinants of improved agricultural technologies adoption in to human, production, policy and natural resource characteristics. Still, others grouped determinants of improved agricultural technologies adoption as continuous and discrete, informational, economic and ecological factors (Wu and Babcock, 1998; Shakya and Flinn, 1985).

A study conducted by Lavison (2013), on organic fertilizer use in vegetable production in Accra, found that male farmers, more likely adopted organic fertilizer unlike their female counterparts. In the study, conducted by Olumba and Rahji (2014), farmers' age, farmland size, household size, educational status, income and extension visit showed significant relationship with the farmers' level of adoption of improved plantain technologies in Anambra State, Nigeria. Furthermore, education and household income play significant role in adopting agricultural technologies on barley production technologies in low rainfall areas (Al-Karablieh, *et.al,* 2009). The study by Degefu, *et. al.,* (2017) on determinants of adoption of wheat production technology package by smallholder farmers in eastern Ethiopia, showed that, age of the household head, farm size, distance from FTC, and annual income of the household dictated the adoption of wheat technology package positively and significantly; while gender of the household head and distance from market influenced adoption.

According to, Muktar, *et. al.,* (2016), understanding farmers' perception about the roles of extension services is a pertinent effort to design better programs that ensure smooth adoption and sustainable production. According to Wossink and Boonsaeng (2003), farmers' perception and knowledge are crucial for successful development. Many promising agricultural innovations and supporting policies failed due to inappropriateness of farmers' needs. Hence, it must be note that the perceived risk of technologies may serve as adoption barrier. The perception of farmers has been also another significant components used to evaluate technological adoption and management efficiency of farmers. Farmers' decision before, during, and after production processes are constrained by on the field and external factors (Abdul-Gafar, 2016).

Ethiopia is one of the least-developed, low-income, food-deficit and poorest countries in Africa (WFP, 2010). The majority (90%) of the poor in the country are relied on agriculture, mainly on crop and livestock production for their livelihoods (CSA, 2009). Despite the importance and potential in economic growth, agriculture in Ethiopia has performed poorly. The low productivity of agriculture in Ethiopia makes the farmers subsistent with no or little surplus (Mulat, 1999), which lead them to be low in their income; then to prevalence and persistence of poverty. Despite reduction in food poverty, the scale of food insecurity and malnutrition in Ethiopia remains serious (WFP, 2011). Food aid was equivalent to 13% of its national output and nearly 30% of households were in extreme poverty (World Bank, 2010). According to Kirwan and Margaret, (2007); Bogale and Shimelis, (2009); Zegeye and Hussien, (2011), Ethiopia receives more food aid than other countries in the world.

On the other hand, Ethiopia's economy has grown by 11% annually, and poverty declined from 38% to 29% in 2004/05-2009/10 (WFP, 2011). However, poverty and food insecurity have continued widespread and remained the main challenges in Ethiopia (EHRD, 2016; African Development Bank/ADB, 2014). Although, in 2009, for example, 72.9% of the populations lived on less than US$2 per day, 27.50% consumed inadequate calories, and 23.6% of children under five are underweight (CSA, 2009); and 40% of HHs were food insecure and undernourished (WFP and CSA, 2014).

In technology adoption, previous studies on personal, physical, economic, and institutional factors were identified on ad-hoc basis, and analyzed separately in a single equation or in a joint bivariate simultaneous equation model (Chilot, *et. al.,* 2015). From an econometric point of view, a single equation could cause bias, inconsistency and inefficiency in parameter estimation unless it has proceeded by examination of complementarity and substitutability among technologies (Greene, 2000). In Ethiopia, different crops and varieties compete for scarce resources such as draft power, labor, chemical inputs, farm land, etc. Hence, analysis of smallholder farmers' decision to adopt a single commodity or a single activity, while farmers are actually made multiple and interdependent decision to adopt multiple technologies leads to failure to recognize interdependencies and endogeneity of activities/ technologies that leads to biased and inefficient estimates (Winters, *et al.,* 2002; Yunez-Naude and Taylor, 2001).

The study conducted by Aman and Tewodros (2016), on Determinants of Improved Barley Adoption Intensity in Malga District of Sidama Zone, Ethiopia revealed that age; farm experience; number of oxen; annual income; membership to cooperative; and distance to all-weather roads determine the intensity of improved barley varieties adoption in the study area. Increased in age affected adoption of barley technologies negatively, whereas, farm experience affected the intensity of improved barley varieties positively. Increase in income affected adoption of improved agricultural technologies positively. However, distance to all-weather road from residence of the household affected adoption of barley varieties negatively. Furthermore, membership to cooperative affected adoption positively and significantly the intensity of adoption of improved barley varieties.

In studies of the determinants affecting the adoption of single improved technology, discrete choice, or probit/logit model can be used. However, using such models is inappropriate to handle simultaneous adoption decision. Multivariate models such as multivariate probit/logit are generally applied to measure and capture decisions involving interdependent choices (Chilot, et. al,2015). According to Dorfman (1996), the bivariate models cannot be use to analyze the choices involving interdependent decisions. Hence, multivariate models such as multivariate probit/logit can be used to handle multiple and interdependent choices in adoption decision of different improved technologies. As a result, in this study, multivariate probit model was employed, since the study aimed to identify determinants affecting multiple and simultaneous adoption decision in adoption of multiple barley technologies.

Barley grain is used as feed and food, for malting purposes, and its straw as roughage for livestock. Furthermore, many factors are responsible for barley yield reduction, such as erratic and poor distribution of rainfall, low soil fertility, minimal or no use of fertilizers, absence of high-yielding varieties, lack of basic knowledge on effective weed control measures and management in barley production (Duwayri, *et. al.*, 1988). In the study area, farm households widely involved in barley production, which is the most important cereal crop for food supply and income of the farm households. The highland agro-ecology of the study area is more suitable for barley.

In the study area, farm households different improved agricultural technologies in their barley production include, fertilizer, manure compost, frequent plowing (three or more times), frequent hand weeding (two or more times), weedicide, farm land drainage, and improved seed varieties. As a result, farm households adopt one or more of technologies in their barley production. Therefore, this study was designed to examine adopters' distribution by the technology types, the influencing factors affecting adoption of these technologies in their barley production, the contributions of these technologies on adopter farm households' income and food availability, and farm households' perception towards agricultural extension service using different analytical methods that include qualitative methods such as (FGD), and using quantitative methods such as descriptive statistics and econometrics models including multivariate probit model, binary and ordered logit models, censored Tobit and multiple linear regression model.

1.3. Objectives of the study

General Objective: The general objective of this study was to investigate determinants of improved agricultural technologies in barley production, farm households' income, food availability and perception towards agricultural extension service; and the roles of barley technologies adoption and farm households' perception towards' extension service to enhance the farm households' income and food availability in the study area, *Semen Shewa* Zone in *Ankober, Basona* and *Angollela woredas*.

The specific objectives of this study analyzed:

- ❖ farm households' barley technologies adoption and its determinants;
- ❖ the contribution of barley technologies adoption on farm households' income;
- ❖ the role of barley technologies adoption on farm households' food availability; and
- ❖ farm households' perception towards extension service in relation to barley technologies adoption, income and food availability;

1.4. Significances of the study

The focuses of this study were to identify the limiting factors in adoption of improved agricultural technologies used to enhance barley yield, thereby, to improve farm households' food supply and income; and to determine the farm households' food availability and income status as well as their perception towards the roles of agricultural extension service in barley technologies adoption. The findings of this study are expected to be useful for many people and institutions (organizations) that include Government, Non-Government, and Community organizations, as well as, for private sectors, researchers, policy makers, development practitioners and for many of others. Furthermore, the findings of this study can also be useful in areas that have similar geographical features, similar farming practices and systems, similar socio-cultural characteristics of the community, especially in the highland areas where the majority of farm households relied on barley production for their livelihoods.

1.5. Scope and Limitations of the study

The aims of this study was to identify determinants of adoption of barley technologies, the contributions of barely technology adoption to farm households' income and food availability, and perception of farm households towards agricultural extension service in

Ankober, Basona, and Angollela woredas of *Semen Shewa* Zone, *Amhara* region, Central Ethiopia. The study used survey questionnaire and focus group discussion (FGDs) for data collection from randomly selected 812 sample households (604 male and 208 female) and from 36 participants in three focus group discussions selected purposively with the consultation of extension workers and community leaders. In addition, secondary data were collect and used in this study. The secondary data were collected from extension workers' offices, from *Kebele*/local administrative offices, from *woreda* office of agriculture and rural development, and CSA web-site.

In this study, for data analyses, descriptive statistics (frequency, percentage, mean and standard deviation); and inferential statistics that include different econometrics models, such as binary and ordered logit, multivariate-probit, Censored Tobit and multiple linear regression models were employed, and in data presentation, graphs, figures, tables and text explanation were employed. For reasons of time and financial resources, the study was not use more analytical models and data presentation techniques.

1.6. Organization of the Dissertation

The dissertation is organized in to eight main chapters and many sub sections. The first chapter comprises introduction, in which background, statement of the problem, objectives, significance of the study, scope and limitation of the study, and thesis organization are incorporated. The second chapter covered Literatures review that focused on the general concepts and theoretical views, and on empirical evidences, followed by conceptual framework development that used as guiding framework in this study. The third chapter encompassed the research methodology and description of the study area, which comprised geographical, demographic and socio-economic descriptions and methods of sample selection, data analyses and interpretations. The fourth, fifth, sixth, and seventh chapters contain the data presentation and the results, as well as discussion of the findings on barley technologies adoption determinants, on farm households' income sources and determinants, on food availability sources and determinants and on farm households' perception and its determinants towards agricultural extension service respectively. The eighth chapter summarizes the key findings, conclusions and recommendations of the study.

CHAPTER TWO: LITERATURES REVIEW

2.1. Theoretical Framework

2.1.1. Theoretical evidences and evolution of agriculture and barley production

The theory of agrarian systems has conceived as an intellectual tool that enable to apprehend the complexity and the construct on a general outline of the historical transformations and geographical diversity of the world's agricultural systems. Agricultural systems that practiced in a given place and time appears complex ecological and economic object, composed of several categories of production units that exploit different types of terrains and diverse species of cultivated plants and animals. Over time, agricultural system has transformed, and different species of agriculture have succeeded one another, forming the stages of an evolutionary series. It has evolved in the world through subsequent domestication of plants and animals from their natural habitats. Furthermore, a change from nomadic lifestyle to farming led the community to become dwellers, eventually spawning the development of languages, literature, science, and technology (Heiser, 1990; Diamond, 1999).

The world has passed through hunter–gatherer, agricultural, and industrial stages (Lund, 1989). Among which, agriculture is the cultivation of plants, animals, and other life forms (Ehrlich and Wilson, 1991; Tuxill, 1999; Toledo and Burlingame, 2006). At the end of the last ice age, 11,000 years ago, the world climatic conditions changed. Temperature increases and altered precipitation patterns led to changes in vegetation. Around 10,000 years ago, there was a shift from foraging to farming that crops suitable for agriculture spread to regions or migrated to new areas. In Near East, wheat and barley; in Far East, rice; in Africa, sorghum & millet; in Mesoamerica, corn; & in South America, potato &other root crops were the dietary staples (Levetin−McMahon, 2008). In Neolithic era, humans began plants and animals' cultivation. As a result, the original ecosystems have transformed into cultivated ecosystems. Hence, agriculture has conquered the world (Mazoyer and Roudart, 2006).

Crop plants domestication began approximately 10,000 years ago at the dawn of agriculture. During the domestication process, early agriculturalists selected among the wild germplasm for material that was better adapted to human use and cultivation. The transition from wild species, crop plants have changed due to selection exerted by ancient and modern plant breeding and cultivation practices (Harlan, 1992). Plant domestication encompasses a broad spectrum of evolutionary changes that decrease the fitness of a plant in the wild but increase under human exploitation and complete dependence on humans for survival and full domestication. Domestication of food plants involved not only profound modifications of human societies but also wild plants genetic changes. Cereals production originated with barley and wheat domestication. Hence, barley (Hordeum vulgare L) was one of the earliest cereals domesticated and has been under cultivation since the beginning of agriculture/ civilization (Morrell and Clegg, 2006).

Barley is the most important crop with greater tolerance often grown in wide range of conditions and in stressed areas such as, in low rainfall, in soil erosion and salinity, in occasional drought, frost, and in abiotic stress areas due to its insects/pests and diseases resistance (Whabi and Gregory, 1989; Birhanu, et. al, 2005). Barley domestication is fundamental to understand its origins and early diffusion of agrarian culture. In Neolithic agriculture, barley is one of the earliest and most important crops. Hence, it sits at the nexus of fundamental technological transformation in human history (Morrell and Clegg, 2006). Humans used barley since longer time (Badr, et. al., 2000. In western countries, barley is increasing in popularity as a food grain and has used in flours for bread making or for baby foods, health foods. Barley can found in regions where other cereals do not grow well due to altitude, low rainfall, or soil salinity. Barley has some useful by-products such as its' straw used for bedding in developed countries, and for animal feed in developing and under-developed countries (Akar, et. al., 2004).

Barley in Ethiopia is one of the most important cereals, mainly grown by smallholder farmers at mid and high altitudes between 2200–3000 masl. In nature, nowhere as Ethiopia, the diversity of barley in forms and genes has observed. Abyssinia/former Ethiopian Empire, could be considered as the center of origin of cultivated barley (Vavilov, 1951). The diverse endemic and botanical varieties may be the result of either an independent domestication or independent development after an introduction from southwest Asia (Negassa 1985; Orabi, *et al.*, 2007). Today, Ethiopia and Eritrea are considered as the centers of barley diversification. Ancient methods of tillage, sowing, harvesting, threshing, winnowing/chaff, dulling and processing, have still practiced by the majority of subsistence farmers in the highlands of Ethiopia (Harlan, 1969).

Barley in Ethiopia has produced mainly for human consumption and it is one of the most important staple food crops (Grando, et. al, 2005; Firdissa, et. al., 2010). It is also the most dependable, desirable and preferable crop by the highland and subsistence farmers due to its early maturity and ability to grow better on poor soil fertility/marginal farms than other cereals (Lakew et al., 1996). The share of malting barley production is quite low (2%) and most is used for making local bread *(Injera)*. Barley grain is used in the diversity of barley recipes that has deeply rooted in the culture and traditions of people's diets. Furthermore, barley straw is a good source of animal feed, and it is a useful material for thatching houses roofs and for use as bedding (Grando, et. al, 2005; Firdissa, et. al., 2010). Barley cropped twice a year. It is most suitable for *Belg*-season production than *Meher*-season production (Yirga et al., 1998a and 1998b).

The home prepared traditional foods from barley include (*Injera, Dabo, Kitta/Torosho, Shorba/Soup, Besso, Zurbegonie, Chiko KOllo, Genfo, Kinche, Atmit/Muk*; and the home prepared traditional drinks made from barley are *tella, areki, borde, Bequre* (Yallew et al. 1998; Molla and Abebaw, 1998; Kerssie and Goitom, 1996), which can be prepared from other cereals. However, barley, after *teff*, is the preferred grain for making of traditional bread, *injera*. It can be prepared, either solely or in combination with *teff* flour or other cereals. *Dabbo* (bread), *kitta* or *torosho, atmit* or *muk,* can also be prepared from barley, or can be blend with other cereal flours. Among local beverages *tella, borde,* and *areki* are the prominent. The most preferred *tella* and *borde*, local drinks, are from barley (Grando, et. al., 2005). Hence, Ethiopia is the largest producer and consumer of barley and various barley products, according to Rashid, et. al, (2015). It is the main ingredient in staple foods in the form of *injera*, porridge, and bread; and local drinks such as *Tella* and *Besso*, and it is useful for malting, animal feed, and house thatching as well as construction.

In 2013/14, household consumption accounted for 64% of total barley production in the country (CSA, 2014). Barley can have added in many food stuffs, such as biscuits, bread, cakes and desserts (Akar, et. al., 2004). According to Kerssie and Goitom (1996), barley can mainly use as a carbohydrate source, although it contains protein. The protein in barley is composed of 19 amino acids, but low in lysine and methionine. This might be the reason that barley recipes are prepared and eaten along with legumes or animal products to supplement the deficient amino acids. The composition of barley depends on the variety and the environment where it is grown, chemical analysis indicated that barley is as nutritious as the other cereals and even better in fiber content. It is a belief that barley is beneficial for its dietary fiber, mainly composed of *B*-glucagon responsible for the reduction of serum cholesterol. Consumption of barley as food in most developed countries has abandoned, but now, its merits for health improvement enable it to regain its importance in human nutrition as in the developing countries (Kerssie and Goitom, 1996).

In Ethiopia, barley covers about 1.13 million (ha), and its national average yield is 1.5 tons/ha (CSA, 2010). The population growth in Ethiopia is rapid (2.9%). Hence, ensuring sufficient food supply/availability is a priority concern. Food barley can play a vital role in alleviating food shortages due to its merits for production and consumption. The annual national average yield of barley is low as compared to its yield potential released food-barley varieties. If these varieties are used in conjunction with the suggested practices in their appropriate niches, can boost production. Some of the major food-barley production constraints include low-yield capacity of farmers' varieties/landraces, inadequate improved varieties, varied agro-ecological zones, lack of appropriate production practices/cultural practices, and management of soil fertility practices. Biotic stresses such as disease, insect pests/Russian wheat aphid, barley shoot fly, and chaffer grub, and weeds/broad leafed and grass weeds, soil PH, and loose linkage between research and extension (Grando, et. al., 2005); Bekele, 1986).

Barley is the most important crop for farm households, since it performs well and grow in frost area, in water logging, in soil acidity and in degraded areas, where other cereals fail. It is also important since it is suitable to grow during the *Belg* season-the short rainy season and (Meher) season, the main rainy season (Mulatu and Grando (eds), 2011). However, despite its long history and wide range of uses, barley yield is very low in Ethiopia, due to poor soil fertility, low-yielding cultivars, poor agronomic practices, diseases and pests (Lakew et al., 1996; Berhane, et.al., 1996; Chilot, et. al., 1998). Barley substitutes for wheat, and barley has supplied the necessities of life (food, feed, beverages and roof thatch) for larger population in the highlands of Ethiopia. Because of its wide range of uses, barley has considered as the "*king of grains*" in much of the country (Abu, 2013).

The theoretical perspectives focused on agriculture, regarding its origin, evolution, and in human history, agriculture has considered as one of the stages in human development, and it has focused in crop and livestock production, which give human beings food, income and other necessities. Among crops, cereals production is the main and most important activity;

and among cereals, barley production, especially in the highland areas, is the most important crop. There is a strong assumption that supported with archeological findings, barley domestication, and then widely production practiced since its starting time approximately, before 10,000 years ago. Therefore, the beginning of agriculture has correlated with the beginning of barley domestication. Improvements on barley varieties genetic constitutions have done through selection and breeding practices, tried to make barley more suitable for production and human consumptions. Ethiopia is considered as one of the origin of barley, and as a place where barley is produced and consumed by its larger population in its highland areas. Therefore, efforts would continue on barley varieties improvement to make it more suitable for the highland environment and for consumption and market and industrial supply.

2.1.2. Agricultural technologies adoption concepts and theory

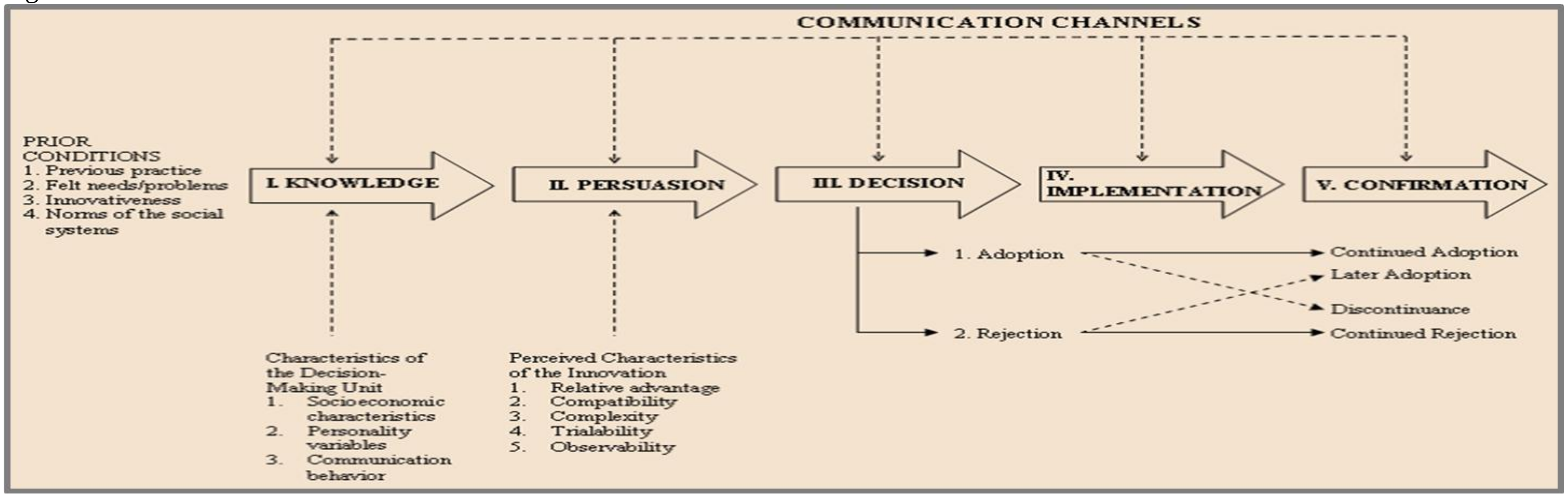
Agriculture is an economic activity with specific characteristics associated with knowledge, innovation and technology transfer (Simin and Janković, 2014). Most rural households are involved in agriculture that includes livestock, crop, or fish production for their livelihoods (Abimbola and Oluwakemi, 2013). Among the total world poor, about 90% relied on agriculture; and live in rural areas. To increase agricultural production and to alleviate poverty, attention need to be given to innovation/technology adoption (Uaiene, *et.al.,* 2009; Bandiera and Rasul, 2010); since, innovation is powerful to enhance agricultural production (Wang, 2013). According to (Rogers, 1983 and 1995), innovation adoption is a time taking process although it induced growth to improve food and nutritional security and alleviates poverty. To heighten production/productivity, a living conditions of rural poor, agricultural technology/innovation should be adopted (Berihun, *et. al.,* 2014). If innovation has adopted, it may alter the existing situations, and can catalyze the change process. However, improved technologies are viable only when they are adopted (Sandra, *et. al.,* 1989).

Adoption is a decision to continue to use an innovation. It is an idea, practice, or object perceived as new by individual or group (Rogers, 1962, 1971; 1983; 1995; and 2003). According to Feder, *et al,* (1985), adoption is a mental process, an individual pass from the first hearing about an innovation to its final use. At household level, adoption can be also defined as the degree of use of the new technology/innovation, after the adopter has full information about it, and its potentials. Adoption is the stage in which a technology has selected for use by an individual/organization; and it is an actual implementation of a new technology/innovation at individual/micro/firm/or household level (Hanel and Niosi, 2007). Adoption of the new technology has influenced by different determinants such as, benefits from innovation adoption by user/adopter and costs of adoption (Hall and Khan, 2002). Adoption is essentially a decision making process comprises a sequence of stages with a distinct type of activity occurring during each stage (Dearing and Permanente, 2012). As a result, innovation adoption/diffusion process consist five stages that include Awareness, Interest, Evaluation, Trial, and Adoption (Ray, 2006). Rogers (1995), initially abided (accepted) these stages, but later, changed the terminologies in to (knowledge, persuasion, decision, implementation, and confirmation) as indicated in Figure1.

Furthermore, decision-making process for innovations as proposed by decision-making model involves five stages that must go through these stages in making decision about adoption of innovation. The stages are information seeking and processing/activities, where individual is motivated to reduce uncertainty about the advantages and disadvantages of innovation. The stages follow each other in time ordered. They influence adopters' decision to adopt or reject an innovation (Roger, 1962, 1983 and 1995 and Dearing and Permanente, 2012). Adopters' categories include (innovators, early adopters, early majority, late majority, and laggards), according to (Rogers, 1962 and 1983; Rogers and Shoemaker, 1971). Among adopters', innovators are local opinion leaders, who test new ideas/technologies, and take risks. Early majorities are deliberate and willing to follow innovators; while late adopters often need peers' pressure/influence in adoption of the new technology/innovation. Laggards are skeptical (doubtful/unconvincing) about the new. So, adhere to the past and adopt at the tail end (Roger, 1960 and 1983; Gezahegn, *et. al.,* 2001).

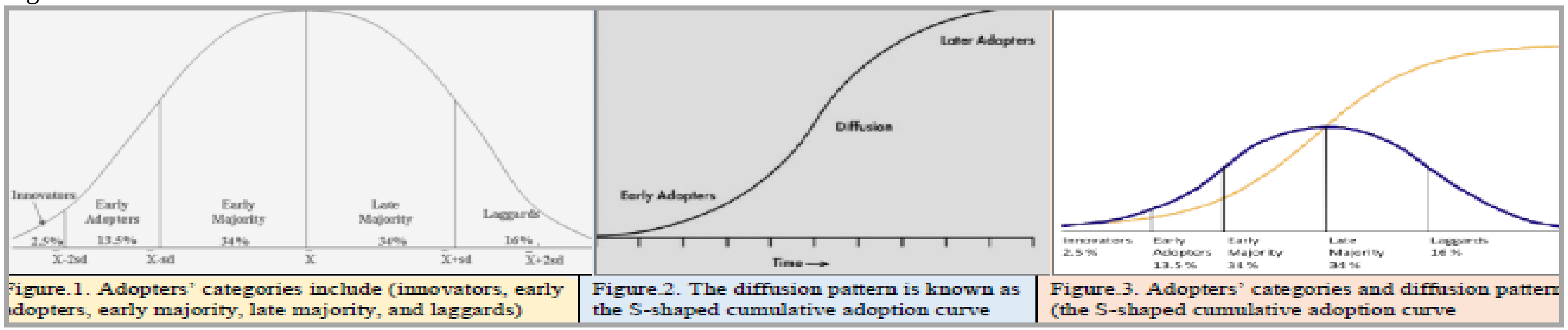
As indicated in Figure1, there are four elements of innovation adoption processes in innovation adoption theory that influence the spread or diffusion of innovation. Adoption process includes innovation, communication channels, time, and social system (Roger, 1962). The graphic presentation of adopters' categories and patterns of adoption indicated separately and in combination in Figure2. In each category, individuals are similar in innovativeness, which is the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than others (Roger, 1960 and 1983; Gezahegn, *et. al.*, 2001).

Figure 1. The Diffusion of Innovation



Source: Rogers (2003)

Figure 2. Different diffusion models



Source: Adapted from Rogers (1962, 1995 and 2003)

Innovation diffusion is the process by which the new technology/innovation spreads among users over time (Norvell, *et. al.*, 2000; Roggers, 1883). It is a special type of communication in that messages are concerned with innovation. It can be predicted/ measured in two ways that include: (i) when innovation diffusion pattern plotted on the curve, it gives an S-shape/cumulative curve; and (ii) in terms of adoption categories that adopters are classified into different categories based on time when they decide to adopt new technology/innovation. Innovation diffusion is the dynamic consequence of innovation adoption and predictability of adoption rate. On the other hand, adoption rate is the relative speed when an innovation has adopted by members of a social system. When individuals adopt new idea, it is plotted on a cumulative frequency over time, the distribution result gives an S-shaped curve as indicated in Figure2, which is an important concept in innovation diffusion theory that predicted/ measured by time length required for a certain percentage of members of a social system to adopt an innovation is rate of adoption (Rogers,1983).

In addition, innovativeness is the degree to which an individual is relatively earlier in adopting new ideas than other members. It is useful to understand diffusion (adoption rates) of a particular technology. The same individual can be an innovator in one technology; but laggard in adopting another technology (Rogers, 2003). Making farmers aware and familiar with innovation to increase their production, extension service providers are responsible. On the other hand, innovativeness is relatively-stable and socially-constructed, which is innovation-dependent characteristic that indicates an individual's willingness to change the familiar practices. It is a notion of openness to new ideas, which encompasses not only one 's overall willingness to uptake the technology and take risks, but also include the personal commitment to make things differently from others (Ogunremi and Olatunji, 2013).

Rate of adoption is the relative speed with which an innovation is adopted by members of a social system. It is generally measured as the number of individuals who adopt a new idea (innovation) in a specific period. Five variables have been proposed to determine the rate of adoption that include, (i) the decision types (optional/free decision, collective, and authority decision), (ii) the perceived attributes of innovations (iii) the communication channels (mass media and interpersonal channels), (iv) the nature of social system (norms or network interconnectedness), and (v) the change agents' promotion efforts. In innovation diffusion theory, innovators are individuals, who first adopt an innovation require a shorter (time/adoption process) than late adopters. The classification of individuals within a social system based on their innovativeness gives adopters' categories (Rogers, 2003).

Diffusion is occurred when an innovation is communicated through certain channels over time among social system members; and it is the stage, when the technology spreads for general use and application (Rogers, 1962, 1995, and 2003). According to Carr (2001), diffusion is the spread of the new technology across the economy/community. In innovation diffusion, when the actual users'/adopters increases, and when the technology/innovation is diffused, its economic impact increases (Hanel and Niosi, 2007). Innovation diffusion can be seen as the cumulative/aggregate result of a series of individual results that weighted the incremental benefits of adopting a new technology against the costs of change, often in uncertain environment (the future evolution of the technology and its benefits); and limited information regarding the benefits, costs, and the availability of the technology, the result of diffusion rate is determined by summing individuals' decisions (Hall and Khan, 2002).

According to Hanel and Niosi (2007), adoption is an actual implementation of a new technology at individual/micro/firm level; while diffusion is the spread of the new technology across the economy/community. Adoption of agricultural technology has a direct effect on farmers' income, yield and on economic growth, if it is widely adopted and diffused (Ibrahim *et. al.*, 2012; Besley and Case, 1993). Adoption of proven technologies and improved farming practices hold great promise to boost production/productivity, to improve the living conditions of rural poor and to reduce poverty. In developing countries, improving the livelihoods of rural farm households via agricultural productivity would remain a mere wish if the technology adoption is low (Udry, 2010; Duflo, *et. al.*, 2011; Ajayi, *et. al,*. 2003; Gemeda, *et. al.*, 2001; Morris, *et. al.*, 1999). Therefore, innovation/new technology diffusion is an important source of economic growth.

Technology adoption is not related to the aspects of the technology alone; but also it needs to pass through complex processes involving users' attitudes and personalities (Venkatesh, *et. al.*, 2012), social influence (1975), trust (Gefen, *et. al.*, 2003), and numerous facilities (Thompson et al., 1991). Individuals adopt innovation, when the valuation of the product is greater than the cost of the product (Hall and Khan, 2002). According to Feder and Slade, (1984); Shampine, (1998); Smale, *et al.*, (1994), in innovation-diffusion model, the technology may be technically and culturally appropriate; but the adoption problem may be information asymmetry and high cost of the innovation. The most important thing to be observed, in adoption decision, is the kind of decision that at any point in time the choice being made, it is not a choice between adopting and not adopting the innovation/new technology; but it is a choice between adopting now, or, later adoption (deferring the decision for other time in the future). The reason is important to look at the decision, because of the nature of the benefits and costs attached to the new technology/innovation.

Unlike the invention (often appears to occur as a single event or jump), diffusion of innovation/new technology usually appears as a continuous and slow process. Yet, it is an adoption/diffusion than invention/innovation ultimately determines the pace of economic growth and rate of change of productivity (Rosenberg, 1972). The reason for S-shape curve is that initially the innovation has to come from outside of social system. This implies that, the number of people exposed to innovation is few in the beginning. As these people in the social system start accepting the innovation, they bring it in contact with more and more people; and the rate of spread keeps on increasing. Eventually, innovation is accepted by most of members of social system and rate of spread declines. As there are no more members left for accepting innovation, the spread stops completely. In these cases, several adoption and diffusion processes may occur simultaneously; such adoption processes may follow specific (and predictable) sequential patterns (Roger, 1960; Hall and Khan, 2002).

The term technology and innovation, they can be used synonymously and interchangeably (Rogers, 2003). The newness of technology/innovation is determined by the person perceiving it. Thus, if a technology is tried for the first time by user, it is an innovation for that user, irrespective of the time it was launched or first used in a social system (Rogers 1962, and 2003). According to Schumpeter (1934) innovation has different dimensions that include (i) introduction of a new good; an improved method; opening of a new market; the use of a new supply of raw materials; and the better organization of an industry; (ii) innovation as a process by which organizations continuously implement new ideas, methods, products or services in order to keep competitiveness (Hurley and Hult, 1998).Therefore, both technology and innovation encompass two components (the hardware and software). The former (hardware) is the physical object that embodies the technology whereas the latter (software) refers to the information upon which a technology runs (Rogers, 2003).

In technology adoption, there are two approaches, (i) the whole package adoption; and (ii) sequential/step-wise adoption of package components. Professionals support whole package adoption; while field practitioners step-wise/sequential adoption. Agricultural extension, in developing countries, there is a tendency of supporting whole package adoption (Leather and Dmale, 1991). Farm households prefer package components adoption one after the other in different time due to the profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints. Farmers might look upon each part of the technological package as a less risky activity than complete package adoption (Ryan and Subrahmanyam, 1975). When technology adoption is based on the relationship between adopted technological components, it is called pattern adoption, which has two dimensions. Then, if farmers adopt technologies in a specific order, the adoption pattern is sequential adoption; and if farmers adopt more than one technology as a package and no specific technology adoption has preceded or followed, the adoption pattern is simultaneous adoption (Rauniyar and Goode, 1996).

In most cases, according to, Mann (1978), agricultural technologies are introduced in packages that include several components, such as high-yielding varieties (HYV), fertilizer and corresponding land preparation practices. While the components of a package may complement each other, some of them can be adopted independently. Thus, farmers may face several distinct technological options. They may adopt the complete package of innovations introduced or subsets of the package that can be adopted individually. In these cases, several adoption and diffusion processes may occur simultaneously. Such adoption processes may follow specific (and predictable) sequential patterns. Furthermore, technology adoption depends on context-specific trade-offs between the new technology and available alternatives. Trade-offs cannot be assessed without first understanding farmers' priorities, the alternatives available to them to address the same problem and the indirect consequences of the technology (Fujisaka, 1994).

Often farmers' priorities are complex. Owing to variability in farmers' resources and priorities, technology's profitability & riskiness will be context-specific, which is problematic when agricultural technologies are bundled into packages (seed, fertilizer and pesticides). For this reason, Byerlee and Hesse de Polanco (1986) argued that technology development should be compatible with farmers' preference for stepwise adoption of technological packages, whereby, they adopt the most profitable components first and the riskier ones later. Farmers' diversify income generating activities to meet their needs such as food, shelter, health, school fees, etc., (Agyeman, *et. al.*, 2014). The livelihood outcomes of households have increased as a result of improvement in productivity, income, wealth, food security, and reduced exposure of households to risk and vulnerability (Uaiene, *et. al*. 2009). Africa's low agricultural productivity has many causes including low knowledge of improved practices, low use of improved seed, fertilize, inadequate irrigation, conflict, absence of strong institutions, ineffective policies, lack of incentives, and diseases (Asenso-Okyere, 2011).

Technology diffusion is critical for growth and development (Perla and Tonetti, 2014). Although many countries have been made significant progress, poverty and malnutrition continue to be the major problems in SSA and Ethiopia. The technology that can improve the crop productivity can be an option for farm community to get rid of hunger and food insecurity by increasing production, reducing food price and making food more accessible to the poor (Just and Zilberman, 1988). according to CIMMYT (1993), farmers to adopt a technology, first, they must know about it. The information may come from several sources. It is important to explore the degree to which farmers have received the information. This will help in analyzing the degree to low adoption may not be a function of the technology, but the information. This analysis is useful for improving extension policies and programs. There are many possible sources of information about new technology. A farmer may learn from his/her own experimentation. Advice and technical information may be available from extension service or the media. If there are many farmers in similar circumstances, the learning process about the new technology may be social. Farmers may also learn about the characteristics of the new technology from their neighbors' experiments (Roger, 1995).

Lack of credible information is one potential constraint in adoption, and social relationships can serve as important vectors/routes/paths through which individuals learn, and are convinced to adopt new technologies/innovations. Firms and extension services that market new products and technologies often rely on information cascades/flows that they need few key entry points, and allow technology to diffuse via ambient/available social learning. Therefore, manipulating this aspect of social leaning could be important to improve policies, if some entry points are better than others, it would be valuable to identify ones that would maximize diffusion. Technology adoption is important, since, it allows people to participate in rapidly changing world where technology has become crucial to lives (Zebib, 2014).

Agricultural growth is essential for fostering economic growth, feeding populations, and addressing poverty in developing world (Datt and Ravallion, 1996; Simtowe, *et. al.,* 2012). Its growth depends on yield-increasing technologies (Hossain, 1989). According to FAO, (2010), in agriculture/ in farming undertaking that occupies daily routine of agricultural producers and involves numerous decisions (what crops to plant, what inputs to use, when to plow, to seed, and how to irrigate, how and when to harvest, how much to keep for consumption, to sell and to store for future sell and use). Literally millions of individuals and households are making such decisions. The world agricultural production need to grow at a faster rate relative to world's population. In this regard, adoption of improved technologies has been viewed as a means to increase agricultural productivity, in farming system transformation and in poverty alleviation in developing countries (Besley and Case, 1993).

In many of less developed countries, agricultural productivity is low. The low adoption rates resulted in low agricultural productivity in SSA (World Bank, 2008). Three out of four people in developing countries live in rural areas. Most of them depend on agriculture, and many live in extreme poverty (World Bank, 2007). Any effort to address poverty must consider agriculture as the central place in developing world. Technology advancement in developed countries, is assumed to be the main factor that has contributed to the development of agriculture in developing countries. Agriculture continues to offer the leading source of employment and contribute large share of national income. Hence, increasing agricultural productivity in developing countries is critical for growth and development. In developing countries, the development of agricultural productivity is through use of improved agricultural technologies and improved management practices (FAO, 2010).

Improving the productivity, profitability, and sustainability of agriculture is the main pathway out of poverty for rural farm households using agriculture for development (World Bank, 2008). Furthermore, promoting farmers' market participation, in developing countries, is an important effort necessary to bring agricultural transformation (von Braun, *et. al.,* 1994). The direct effects of the new agricultural technology on poverty reduction are the productivity benefits enjoyed by farmers (adopting new technology). These benefits manifest themselves in the form of higher incomes. The indirect effects of productivity are the induced benefits passed to others from the technology adopters. These may comprise lower food prices, higher non-farm employment or increases in consumption. The impacts of higher-order (indirect) benefits from technology adoption depend on the elasticity of demand, outward shifts in supply lowering food prices; and increased productivity, which may stimulate the demand for labor. Productivity-enhancing technology involves a bundle of innovations rather than just a single technology (Sahu and Das, 2015).

Adoption of improved technologies has been guided and influenced by three paradigms/models that include innovation-diffusion, perception of adopters and economic constraint (Feder and Slade, 1984; Shampine, 1998). The first paradigm is the innovation-diffusion paradigm that deals with information dissemination (Adesina and Zinnah, 1993; Rogers, 2003). The second paradigm is the economic constraint paradigm that asserts/contends that technology adoption is influenced by utility maximization & economic constraints due to the existence of resources distribution asymmetry. It is also asserted the input fixity in short run, such as credit, land, labor, and other inputs. Access limits, production flexibility and conditions of technology adoption (Deressa, *et. al.*, 2008; Aikens, *et. al.*, 1975; Smale, *et. al.*, 1994; Shampine, 1998). Third, the adopters' perceptions paradigm posits/theorizes that adoption process starts with the problem of adopters' perception and the proposed technology (Adesina and Zinnah, 1993). It argues that perceptions are important influencing factors of adoption; although they are context and location specific due to heterogeneity factors that influence them such as culture, education, gender, age, resource endowments and institutional factors (Posthumus, *et. al.*, 2010).

Adopters' perception paradigm (model) suggests the perceived attributes of the technology conditions. Farmers, even with full information, they subjectively evaluate the technology differently than scientists (Ashby et. al., 1989; Ashby and Sperling, 1992). Thus, understanding farmers' perceptions is crucial in the generation and diffusion of new technologies and farm household information dissemination. The improved agricultural technologies, their adoption and diffusion among farm households are vital to enhance agricultural production, thereby, the living standard of rural community by improving their food security and income. However, adoption of improved technologies by farm households is not as such easy. Hence, it needs strong efforts and high resource allocation. Furthermore, it needs available and easy accessible, improved agricultural technologies for dissemination and adopted by the farm households. The widely accessible information and improved technologies are vital to transform the traditional agricultural production system in to more productive one. Furthermore, to transform the traditional agricultural production system, well organized extension and market oriented production, as well as processing of primary agricultural products and marketing them as well as infrastructure facilities, are some of the most important conditions need to be available and well organized.

2.1.3. Agricultural extension: concepts, theories, evolution and roles in agricultural development

The evolutionary growth process of agricultural extension science showed that first evolved from rural sociology; and over time it has aligned more with social psychology and communication (Röling, 1988). It has been assumed that all farmers eventually would adopt the new innovations after observing the benefits of innovations. Hence, the measure of the views of adopters and their views towards the adopted innovations would be based on the adoption levels of the innovations. Furthermore, increased adoption of innovation is possible through increased information and innovation communication, such as, through farmers' networks. This organized and formal communication processing of information is called agricultural extension, which is the voluntary based behavioral change via communication (Botha and Atkins, 2005). Farmers require necessary knowledge and information both to use technologies that can generate economic returns; and to manage any associated risks (Baumüller, 2015). The discovered agricultural technologies have to be disseminated and adopted by users through effective extension services (Cole, 1999; Shah, *et. al.*, 2014).

In helping small-scale farmers to adopt improve and yield enhancing technologies/practices, agricultural extension plays a vital role through knowledge based information provision; and in addition, extension helps farm households to access credit, inputs and markets along the value chain that have the potential to increase agricultural productivity and income (Mengistiee and Belete, 2016). Agricultural extension is concerned with two basic functions that include, (i) dissemination of useful and practical information; and (ii) practical application of such knowledge on farm and home situations. When these are conducted in the non-formal atmosphere with adults (the main clientele), it is called agricultural extension service (Obibuaku, 1983). Extension is both a political and organizational instrument to facilitate development. Its' role/service ranges from transfer of mono-crop technology to participatory problem solving educational approaches with the aims of reducing poverty and enhancing community involvement in development (Rivera and Qamar, 2003).

In many rural settings, access to adequate knowledge, improved technologies, financial services and other relevant services are critical (IFPRI–World Bank, 2010). Agricultural extension works in a wider knowledge system embraces different components such as research and agricultural education (Rivera, *et. al.,* 2001). There are significant challenges in providing extension services. These challenges range from insufficient funds to support public extension, poor resourcing, disorganized structures resulting in poor infrastructure, limited involvement of rural farmers and populations in extension processes-to lack of appropriate strategies for effective research and adequate extension methods. Limited coverage of extension services across rural regions and challenges in adapting technology packages to community-specific contexts have also been highlighted as critical issues in the delivery of extension service (IFPRI–World Bank, 2010).

Agricultural extension is important, it is because, (i) it can organize, assembled, synthesized, blended and make available information about goods, new practices, and innovations from research station and from farmers' experience in a way that it can be used in adoption; (ii) the information, then can be used for educational or for knowledge dissemination purposes; and (iii) then, extension results in organizational and administrative set-up that creates easy environment for technologies dissemination. The goal of extension is to determine how to convey information about the new innovation to the users (farmers) to make easy adoption decision. Hence, designing appropriate communication channel, which is the challenge, in extension is vital (Röling, 1988). Over time, within the field of extension, it is used by including different advisory service, consultation, technology transfer, research, training, marketing, industry development, learning, change, communication, education, attitude change, collection and dissemination of information, human resource development, facilitation, or self-development activities that are undertaken with the aim of bringing positive change on farms and agriculture (Fulton, *et. al*, 2003).

In developed countries, agricultural extension has largely been institutionalized, top down, and focused on delivering specific, often commodity-based, technical advice to farmers to increase production and profitability. This centralized transfer-of-technology model has inherent biases that tend to favor resource-rich farmers, but may not resource-poor farmers. In addition, extension services are constrained by distances, time, and costs to provide its service to the farmers. The conventional face-to-face extension services meet the needs of only a small proportion of farmers (Anderson and Feder, 2004). One of the key problems of public extension services in developing countries is the incentive failure by extension services to respond to clients' needs and accountable to them (World Bank and IFPRI, 2010), which caused largely by bureaucratic structure of extension administration, few rewards, poor facilities, meager/in-adequate prospects of promotion, and low recognition for extension agents (EAs), which lead to low motivation and morale (Bitzer, 2016).

Agricultural extension approaches that deliver timely, targeted, and cost-effective supports to farmers help to ensure sustainability &adaptive capacity of agriculture, by increasing productivity and minimizing associated environmental impacts. To achieve these services, it needs to incorporate latest and relevant developmental science that include climate and agricultural sciences and research into education &learning (Mushtaq and Khanam, 2017) to overcome the declining of farm productivity, and to improve farmers' production techniques through agricultural extension service help the flow of information, transfer of knowledge and scientific findings. Extension isn't merely occupying a bridge position, but also holding the roles to improve efficiency and effectiveness of farmers and research institutions, and to facilitate transfers of agricultural technologies among farmers through knowledge management and ends up with human enrichment. Agricultural extension by its nature need to play the role in promoting adoption of new technologies/innovations (Rivera, *et. al.*, 1997).

Extension theory helps to understand the contextual factors of adoption process and it provides insights about communication aspects that influence adoption decision. Extension approach is not about studying or analyzing innovations adoption. Rather, it is about bringing the behavior change of farmers/clientele. The approach does not provide a framework for studying adoption of innovations and evaluating extension outcomes (Botha and Atkins, 2005). Agricultural extension brings changes through education and communication in farmers' attitude, knowledge and skills. It involves dissemination of information; building capacity of farmers through use of a variety of communication methods and help farmers to make informed decisions. Worldwide, the public extension sector plays dominant role in the provision of extension service (Axinn and Thorat, 1972; Lees, 1991; Swanson, *et. al.*, 1997). Extension service effectiveness is highly dependent on extension workers' ability who need to be competent/capable enough, since the whole extension process is dependent on them, to transfer information from extension organizations to the clients (AL-Sharafat, *et. al.*, 2012).

According to Axinn (1988), there are eight extension approaches that include: (i) general extension-aims to boost national production through adoption of recommendations; (ii) commodity specialized-focused on specific crops production improvement; (iii) farming system-focused on local farming communities to adopt technologies provided by the program; (iv) training and visit (T&V)-increment in production of particular crops covered under the extension program measures using training and visiting methods; (v) participatory extension approach-focused on the number of farmers that are actively participating and benefiting from the extension program; (vi) educational institution approach-focused on farmers' participation and attendance in extension services of the educational institutions (schools, colleges and universities); (vii) project approach-this comes with short term projects and has focused on changes that can be achieved in a short period of time; and (viii) cost sharing approach-focused on farmers' willingness to share the cost incurred by the program individually or through their local institutions.

When we come to Ethiopian, the above mentioned approaches were applied separately or in combination, under different policy regimes. Extension in Ethiopia started during the imperial regime. The base for its commencement at that time was the agreement between the United states of America (USA) and Ethiopia signed in 1952 with broad mandate, such as high level manpower training, extension promotion, and dissemination of research output and scientific information using agricultural extension as a network (Abesha, *et. al.,* 2000). During that time the country was without any trained manpower and to fulfill the above objective, the now Haramaya University was established in the same year as the agreement. The collage played significant role in establishing agricultural extension in the country shouldering the national mandate to develop and deliver agricultural extension programs. However, as of August 1963, the mandate was transferred to Ministry of Agriculture. Then, the college's effort was concentrated to reach only farmers in the vicinity (Belay, 2003).

According to Wale and Yalew, (2007), the different extension approaches in Ethiopia were in place to avoid the problem of their predecessor. For example, MPPs replaced the comprehensive package programs because the comprehensive package programs (CPP) were expensive and not applicable for poor farmers. The MPPs were also found to be in favor of wealthy farmers and replaced by PADEP. These are more or less the same as contemporary extension program attempted in the 1960s. However, the newly implemented package program was designed based on a thorough evaluation of efforts applied in the field of agricultural extension in the country for the past three to four decades. Since the mid-1960s, there were also extensive efforts in research focused on testing fertilizers and key crops in different areas of the country by FAO and the then Imperial Institute of Agricultural Research. This resulted in Minimum Package Program (MPP) in 1971. The MPP was applied at different stages (MPP I and MPP II), of which only MPP I was applied in the imperial period) and tried to link external inputs (fertilizer and seed) to credit facilities with the narrative in favor of Green Revolution (Keeley and Scoones, 2000).

In Ethiopia, by September 1974, the country entered in new era, as a result of revolution. The imperial regime was overthrown and the military force took the power. Some drastic changes happened, of which the March 4, 1975 land reform proclamation that was banned private ownership, prohibited land transfer through sale or mortgage, declared land distribution to tillers without compensation to private owners (Belay, 2003; EEA, 2006). The proclamation contained the establishment of peasant association as the basic instrument for the implementation of land reform. A peasant association has to cover an area greater or equal to 800 hectares and 250-270 households as members (Belay, 2003). Under the military regime, two extension programs, the MPP II and PADEP were implemented. MPP II was planned to be implemented in (1975-1979). However, due to the political instability in the country it was not implemented. After the establishment of producers' and service co-operative in 1978, the MPP II was reinitiated and implemented in (1981-1985) with the support of (IFAD), (WB), and SIDA. However, PADEP came in, due to the shortcomings of MPP II in 1985 that was emanated/came from the limited resource capacity of the country towards developing technology that fit into highly diversified ecological and social setup (EEA, 2006).

The formulation of PADEP divided the country into more or less homogeneous zones, and set different objectives to different zones. Bases on climate, geographic, resource endowments, and cropping patterns, the country was divided into eight agricultural development zones whereby 235 districts (181 cereal producing and 54 coffee producing districts) were selected as surplus producing districts (Belay, 2003). Some of the objectives of PADEP were to boost national food production, to promote cash crop, to expand cooperatives in rural areas, to create employment opportunities for rural communities, and to avert/prevent soil loss (soil erosion). The program's approach to reach the farmer was a modified version of the Training and Visit (T&V) system whereby one DA is assigned to 1300 farmers in contrary to the conventional T&V, which assigns 800 farmers per single DA (EEA, 2006).

Under the current regime (FDRE) regional states are responsible in executing extension service; while (MoA) has the mandate of policy formulation, coordination of inter-regional projects and development programs, provision of training and technical support to raise the competence of staff at regional level. The basic approach is the package approach and there are different packages. Some of the major packages are: extension package that bases on cereal crops, package for high value crops, package for livestock, package for soil and water conservation, package for agroforestry, and package for post- harvest technology. The Federal Democratic Republic of Ethiopian government, currently in the country opts/decides ADLI as a general strategy of food security and poverty reduction in the country. To realize the strategy, PADETES was adopted as a national extension system as of 1994/95 (Abesha, et al, 2000). However, the approach followed by PADETES, was first introduced in the country by an NGO called Sasakawa Global 2000 (SG-2000), on 160 farmers in two regions (Oromiya and South Nations, Nationalities and People-SNNP) in 1993 with farmers' wheat and maize Extension Management Training Plots (EMTPs), according to (EEA, 2006).

Problems with the current Ethiopian extension service, according to Mengistie and Belete (2016), has characterized by top-down, non-participatory, supply driven not demand driven, gender bias extension, lack of staff morale, capacity and capability of staff, development agents' involvement in non-extension activities, lack of qualified extension supervisors, insufficient appropriate and relevant technology, options both for crops and livestock sector, inadequate public funding. However, future extension services of the country are planned to center around the use of FTCs, which are constructed at *Kebele* level with the participation of the farmers themselves. The constructed training centers are expected to serve as extension information center, a place for modular base farmers training up to six months, technologies demonstration, and source of advice, center of indigenous and improved knowledge. FTCs are envisioned/intended to facilitate rural transformation than only limited to agricultural development, to operate wider principle of human resource development than limited only in transferring technologies (TOT), and also envisioned that DAs will not be involved in input supply and credit collection and in other non-extension activities. It is also expected to play active role in linking farmers with other institutional support services such as input supply, credit service, cooperatives and marketing of agricultural products.

Extension theory helps to understand and guide to design extension policies, strategies, programs, services and activities. In addition, the theory also provides insights about the importance of communication, the way to disseminate extension information and improved technologies/innovation. On the other hand, understanding the evolution of extension help to learn and develop experiences from the evolution of extension that help to avoid the previous problem, aware the challenges and to design innovative extension strategy. Extension service in the world plays a pivotal role in adoption and diffusion of agricultural technologies, which are vital in improving agricultural production, thereby, the income and food availability/food supply of the farm households. In extension, the ultimate goal is to improve the farm households' yield thereby, their income and food supply through dissemination of improved technologies, information how to use and where to get the technologies that help to alleviate poverty and ensure farm households wellbeing.

2.1.4. Perception: concepts, theories and perception roles in extension, adoption and innovation diffusion

The term perception is derived from the old French language term was percepcõÈon, which referred to the collection of rents by feudal landlords (Barnhart 1988). The current definition of perception has maintained a degree of this prior usage in that it refers to the collection of information about the world by means of the senses (cf Simpson and Weiner, 1989). In a similar vein, the Latin terms (percept Hwo, percHwpHwo and perceptio} nem), mean to take possession or to seize, be it physically grasping or mentally seizing of something with one's senses (Lewis and Short, 1975). Fundamental/essential/basic to perception is, first, the person/perceiver; secondly, something being perceived; thirdly, there is the context of the situation in which objects, events or persons are perceived and finally, there is the process of perception starting with the multiple stimuli by the senses and ending with the formation of percepts. Although it may appear from the abovementioned to be a separated and slow process, cognizance/understanding must be taken that the formation of perception takes milliseconds to complete and are not fragmented (Jordaan and Jordaan, 1996).

Certain conditions have to be met before perception. The first is that there must be a normally functioning of sensory system secondly, the sensory system must be subjected to basic sensory stimulation; thirdly, the stimulation can be in a constant state of flux/change, both physiologically and psychologically (cf Tibbetts, 1969). In order to understand how human

gives meaning to their world, one has to understand the perceptual process as well as the various influencing factors. With regard to the influencing factors, according to Cantril (1968), any perception as an awareness emerges as a result of a most complicated weighing process taking into account the whole host of factors or cues/clue that follows by conceptualization of the perceptual process, which is the mere understanding of the process.
The perception definition implies that the first step in the perceptual process is the experiencing of multiple stimuli by means of five senses. Physiological differences and deficiencies in individuals may cause them to perceive differently. In this instance, Coren, Ward and Enns (1999) note that "***your world is what your senses tell you. The limitations of your senses set the boundaries of your conscious existence.***" According to Randolph and Blackburn (1989), the final step in perceptual process is the assignment of meaning to the perceived phenomena. In order to understand others' and our own behavior, the process of attribution comes into operation. With reference to social context, while observing others in specific situations, humans make judgments and attribute meanings based on observed behavior (Cushner et al., 1992; Finchilescu, 1992; Baron and Byrne, 2000).

Perception is closely related to attitudes. It is the process by which organisms interpret and organize sensation to produce a meaningful experience of the world (Lindsay and Norman, 1977). In other words, a person is confronted with a situation or stimuli. The person interprets the stimuli into something meaningful to him/her, based on prior experiences. However, what an individual interprets or perceives may be substantially different from reality. The perception process follows four stages: stimulation, registration, organization, and interpretation. A person's awareness and acceptance of the stimuli play an important role in the perception process. Receptiveness to the stimuli is highly selective and may be limited by a person's existing beliefs, attitude, motivation, and personality (Assael, 1995). Individuals will select the stimuli that satisfy their immediate needs (perceptual vigilance) and may disregard stimuli that may cause psychological anxiety (perceptual defense).

According to Allport (1935), attitude is a mental or neural state of readiness, organized through experience, exerting a directive or dynamic influence on individual's response to objects and situations to which it is related. It is a mindset or a tendency to act in a particular way to both individual's experience and temperament. Attitude includes three components: (i) affect (a feeling), (ii) cognition (a thought/belief), and (ii) behavior (action). Perception refers to beliefs or opinions often held by many people based on how things seem to them.

Knowledge, on the other hand, concerns the way people understand the world, and how they interpret and apply meaning to their experiences. Both perception and knowledge guide decision making (Kisauzi, et. al., 2012). Therefore, farmers' perception refers to their personal subjective evaluation of an innovation attributes (Rogers, 2003).

Farmers' perceptions on characteristics of technology lead to positive or negative attitudes towards innovation and these attitudes affect farmers' willingness to adopt technologies (Adesina and Zinnah, 1993). According to Rogers and Shoemaker (1971), perceived ease use is the degree to which a person believes that using a particular system would be free of effort. A distinction should be made between perceptions of an innovation and adoption (Moore 1987 and 1989). Technology adoption has also been analyzed by considering farmers' perceptions. Studies mainly focused on the perceptions of farmers hold on certain characteristics associated with technologies and on how these perceptions influence adoption (Pereira, 2011). The decision to participate in new agricultural technologies depends on farmer's perception which is a key in influencing adoption (Negatu and Parikh, 1999; Adesina and Baidu-Forson, 1995).

According to, Adesina and Baidu-Forson (1995) farmers, as consumers of agricultural technologies, have preference for particular attributes of technologies; and their perceptions about these attributes particularly affect their adoption decisions. Farmers' beliefs, attitudes and perceptions are influential aspects in adoption decisions. Although they may not be sufficient to explain all of the variance in behavior, they inform farmers' intentions towards a particular behavior. Positive beliefs, attitudes and perceptions usually lead to predisposition for adoption whereas negative feelings reduce the chances of voluntary adoption (Pereira, 2011). Feather and Amacher (1994) argued that to increase technology uptake, it is necessary to understand perceptions working as barriers and promote information dissemination and education to allow farmers to change negative beliefs, attitudes and perceptions.

Literatures have shown that understanding the perception of the community towards the planed practices, is vital for the successful implementation of the planned activities. Without knowing the communities' perception, the end result of the planned activities might be failure. Peoples' perception towards' the planned activities, which are going to implement by them is their belief and acceptance as well as taking the risks associated with the planned activities. Therefore, it is the priority issue to understand the perception of the community before disseminating the new technologies. Hence, in this study, the aim was to understand the farm households' perception towards agricultural extension service in relation to its role in adoption of barley technologies, income and food supply/availability of households.

2.1.5. Household income: concepts and theory

Income is the consumption and savings opportunity gained within a specified timeframe. In economics, it refers to the accumulation of both monetary and non-monetary consumption that the sum of revenue earned minus expenses. It can be used to increase the growth of assets (Barr, 2004; Case and Fair, 2007). The concept of income can be defined as the maximum amount consumed by the household in a given period, while keeping real wealth unchanged. The income concept includes all income received by the family/household, whether or not it is fully taxed, partially taxed, or untaxed (Bricker, *et. al.*, 2016). According to Harris (2005), income is regarded as how much can be consumed without future impoverishment. It is the maximum amount an individual spend/consumed; while keeping real wealth unchanged (Zacharias, 2002). Income acknowledges the well-being of individuals determined not only by the level of one's own income, but also by its relation to others' income (Ferrer-i-Carbonell, 2005).

An aggregated (total) income of household indicates the welfare of the household, which may be from different sources (Weitzman, 1976). Income consists all cash, kind, or services that are usually recurrent/regular and received by the household or individual members at annual/frequent interval time from employment, own business, lending assets, from government (income transfer), private institutions and households, the value of services provided from the household via the use of dwelling place, other consumer durables owned by the household and unpaid household work. During the reference period when they are received, such receipts are potentially available for current consumption and, as a rule, do not reduce the net worth of the household. Hence, household income can be conceptualized as the sum of income and revenue minus expenditures (ILO, 2001). The different sources of household's income can be wage and non-wage, dependent and independent that a household can earn over a specified time (Covarrubias, *et. al.*, 2009).

The main categories of household's income can be agricultural/non-agricultural wages, crop and livestock sources, self-employment (non-farm enterprises), transfers and other non-labor sources. According to Census and Statistics office of Sri Lanka (2013), the total income of the household can be either in cash (monetary income) or in kind (non- monetary income) from sources such as (i) wages and salaries, (ii) agricultural activities (seasonal crops/ non-seasonal crops), (iii) non-agricultural activities, (iv) other cash receipts such as pensions, dividends, rents, interest amounts received from various types of savings, current remittances and local and foreign transfers, (v) income by chance/ad-hoc gains such as compensations, lottery wins, etc. and sales of goods and savings, and (vi) Income in-kind.

Income in terms of broad sources, (i) income from employment that comprises receipts from involvement in economic activities that consists of employee income (wages) and self-employment income (return to labor); (ii) property income from ownership of financial and other assets (interest payments); (iii) income from household production of services for own consumption (services of owner-occupied housing, household production of domestic services for own consumption); (iv) transfers received in cash and goods from government (pensions), others (alimony/grant, parental support) and non-profit institutions serving households (NPISH) such as (scholarships, strike pay); (v) transfers received as services such as social transfers in kind, and care services from other households (SNA, 1993).

The rural household income, according to (Lazarus, 2013), is mainly derived from farm and non-farm sources, which played vital role in household economy. Traditionally it was thought that rural households in developing countries only participated in agriculture. However, research has shown that rural households actually participate in a variety of income sources (on the farm and off the farm). According to Maltsoglou and Rapsomanikis (2005), income from agricultural can be broken-down into own production consumed in household and cash income. Own production consumed in household is the foregone income, since the produce instead of selling to generate profit. Hence, it indicates the subsistence level of the household. Regarding the income-sharing unit, it can be the family group (consists naturally related members); or the household group (naturally related or unrelated members that cohabit to share some resources and economies of scale). The income sharing units come together to share the same dwelling place and economic units (Smeeding and Weinberg, 2001).

Income captures the consumption expenditure, which is a more appropriate economic indicator (Blundell and Preston, 1998). There is an argument that more income allows people to satisfy more preferences, resulting in increased well-being (OECD, 2013). Households have personal needs and wants that are directly satisfied through consumption of goods and services (SNA, 1993), a household pays for the direct satisfaction of the needs and wants of its members, which can be done, (i) through direct monetary purchases in the market; (ii) through the market-place but without using any money as means of payment (barter, income in kind); or (iii) from production within the household, which is own-account production (ILO, 2003). According to Kidane, *et al.*, (2006), agricultural technology can contribute to increased agricultural and rural incomes that leads to (better food access), food production (food availability), and to other sectors and contributes to economy wide growth. But in Ethiopia smallholder farming is the dominant livelihood activity and the source of vulnerability to poverty and food insecurity due to low use of improved technologies.

The concept of income is regarded as households' expenditure paid for maximum consumption to satisfy households' wants and preferences without future wealth impoverishment. Furthermore, income is the maximum amount consumed by the household in a given period, while keeping real wealth unchanged. Households and individuals' income is the sum of all wages, salaries, profits, interests, payments, rents, and other earnings received in a given period. Literatures show that income is necessary for the growth of assets. Income encompasses both household's consumption and savings. When the household's income is greater than total consumption, it is saving that can be used for investment and asset enhancement. As literatures show, income categories include both monetary and non-monetary values; and agricultural and non-agricultural categories. Investigating the status and income sources of the farm households is pertinent to design strategies and policies to fill the gap, alleviate poverty, and improve the wellbeing of the farm households.

2.1.6. Household food availability: concepts and theory

Originally, food security was described as whether or not a country has enough food to meet its requirements. It was implied the ability of a nation to meet the food needs of its people, suggesting self-sufficiency (Pinstrup-Anderson, 2009). Furthermore, household's food security is defined as year-round access to adequate supply of nutritious and safe food to meet the nutritional needs of household members (men, women, boys and girls (WB, 2009). Food availability is the first approach of food security with the core ideas traced back to Venetian thinker Giovanni Botero (1588). It was popularized by Thomas Malthus (1789). It is, according to Irohibe and Agwu (2014), enough safe and nutritious food that either domestically produced or imported. It was known as the Malthusian approach, which was focused on the (dis) equilibrium between population and food. In order to maintain this equilibrium, the food availability growth rate should not be lower than the population growth rate. Hence, food security in this view is a matter of aggregate (per capita) availability. In closed economy, it depends mainly on food production and stocks, while in open economy food trade can play a relevant role (Burchi and De Muro, 2012).

According to FAO (2005), terms such as food security and insecurity are used to describe households, whose food security status is below or above the minimum standard (which means to describe whether they have access to sufficient quality and quantity of food supply). The concept of food security was started in the mid-1970s at global food crisis discussion at international level. The initial focus of food security was to ensure adequate availability at the international and national levels. According to Duffour (2010), perceiving food availability at global level cannot assure food security at national level and perceiving food security at national level doesn't ensure food security at household and individual levels. Inadequate nutrition is considered as measure of poverty in many societies synonymously to poverty. Households consuming less than minimum calories required for its members to stay healthy and maintain regular physical activity can be classified as food energy deficient households; while households consumed greater than or equal to the minimum calories are classified as households with non-caloric food energy deficit (Smith, 2007; WFP and CSA, 2014).

Until early 1970s, the food security reference was food availability; and it was well reflected in World Food Conference (1974) that food exists or available at all times in adequate quantity that supplies basic food foodstuffs to the world to sustain a steady expansion of food consumption and to offset fluctuations in production and prices (UN, 1974). The concepts of food security since its beginning in 1940s, its meanings have been shown changes and progresses. The 1970s, food security's definition to food-supply/food availability focused to ensure all people to have enough food to eat; and in 1980s, food access and consumption became prominent through Sen's 1981 entitlement approach that highlighted food related problems that are not only influenced by food production and agricultural activities, but also by structure and processes of the entire economies and societies. Hence, food insecurity has been caused not only by scarcity but also by institutional failures. Multi-sectoral planning was introduced to tackle food insecurity (Dreze and Sen 1989; von Braun, *et. al*, 1992).

Following the concept of food access, the widely accepted definition of food security developed at the 1996 World Food Summit that emphasized on its multidimensionality; and it was a little bit improved in FAO (2002) definition by adding [social] that says "Food exists, when all people, at all times, have physical, [social] and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. This FAO's definition of food security comprises four pillars that are availability, accessibility, utilization and stability (Pangaribowo, *et. al.,* 2013; Mohammed, 2003; and World Food Program, 2009). According to, Omonona and Agoi, (2007); Ayatoye *et al,* (2011); Jrad, *et al*, (2010); IFAD, (2012); Upton, *et. al*., (2016), there is a general agreement on the four distinct food security variables, namely (food availability, access, utilization and stability) to attain food security; while food insecurity, on the other hand is the uncertain access to enough and appropriate foods (Barrett, 2002).

According to Simon (2012), food insecurity as defined by FAO is a situation where some people do not have access to sufficient quantities of safe and nutritious food; and hence, people do not consume food they need to grow normally and conduct active and healthy life. Food insecurity may be due to (lack of food, no availability, lack of resources, no access, improper/no proper utilization, changes in time, and no stability). Among the four dimensions of food security, the first is food availability. It refers to the sufficient availability of food that present in a country or area through domestic production, imports, food stocks, food aid, etc., (WFP, 2009). The definition does not only apply to countries or areas but also to villages and households (Simon, 2012). The second dimension is food access, which refers to the physical, economic and social accesses to food (WFP, 2009), which was first presented by Amartya Sen in early 1980s (Simon, 2012).

Under the concept of food access, there are three elements that include (physical, financial and socio-cultural) food accesses. The physical food access is a logistical dimension. A food produced in the country or area but in another region with limited or no transport facilities between both regions and lack of information, the available food is inaccessible to the location where people (households, etc.) actually need it. The economic aspect of food access is that food commodities are available where people need it and households have the financial ability to regularly acquire food to meet their requirements. The social (socio-cultural) food access refers to food commodities are available physically near to the consumer that they may have resources to acquire them, but due to socio-cultural barriers some population groups, for gender or other social reasons, are limited to access the food (WFP, 2009).

The third dimension of food security is food utilization, which refers to safe and nutritious food to meets people's dietary needs. It is not sufficient that food to be available and accessible to households to ensure people to have a safe and nutritious diet. A number of elements intervene here such as: selection of food commodities, food conservation, preparation and nutrients absorption. Food need to have good quality and safe. Food utilization is also related to clean water, sanitation and health care. The food utilization dimension, thus, is not only refers to nutrition but also to the conservation, processing and preparation. People living where food is available, having a full access to food are still suffering from malnutrition mainly because of a non-correct utilization of food (WFP, 2009).

The fourth dimension of food security is food stability, which applies to the previously mentioned three food security dimensions (availability, access and utilization of food). Food security is a permanent and a sustainable situation that cannot occur at a moment, a day or a season. On the contrary of food stability, food security dimension, chronic and transitory food insecurity, which are long term/persistent inability to meet minimum food requirements; and transitory food insecurity is a short term/temporary food deficit, respectively. There are also cyclical food insecurities such as seasonality food insecurity, which implies that keeping food stability is alleviating the food insecurity dimensions (WFP, 2009). The policy implications of food availability approach are twofold that include on the demand side (i) the need to reduce the rate of growth of population–namely the fertility rate–through appropriate policies; and (ii) the need to boost (per capita) food production–namely agricultural production. For such purpose, the foremost policy that is generally prescribed and implemented to increase agricultural productivity (Anderson, 1990).

The food security focus has moved from a global and national perspective to households and individuals. This is due to the increased observations of inequalities in the sufficiency of food intake by certain groups, despite the overall food supply. Hence, the main goal of food security is for individuals to obtain adequate food needed at all times, and to be able to utilize it to meet the human body needs (Anderson, 1990). Since food is the basic need and necessity to life, it must be satisfied before other developmental issues (Datt, *et al.*, 2000). After the 1970s the Malthusian ghosts/suggestions of food scarcity have been reinvigorated/strengthen by the increasing ecological concerns, and related concepts such as carrying capacity and ecological footprint/mark (Burchi and De Muro, 2012). A total of 925 million people are undernourished in the world. In Sub-Saharan Africa 30 percent or 239 million people are undernourished, the highest proportion of all developing regions (FAO, 2010).

Plummeting/reducing food insecurity continues to be a major public policy challenge in developing countries. Achieving of food security in any country is an insurance against hunger and malnutrition, both of which hinder economic development (Davies, 2009). This is why all developed and some developing countries make considerable efforts to increase their food production capacity. Approximately one billion people worldwide are undernourished, many more suffer from micronutrient deficiencies, and the absolute numbers tend to increase further, especially in Sub-Saharan Africa (FAO, 2008). Achieving sustainable food security, the basic right of people to produce and/or purchase the food they need, without harming the social and biophysical environment, is a major challenge in the world of rapid human population growth and large-scale changes in economic development (Foley, *et. al*., 2011).

Sub-Saharan Africa is the poorest region in the world (Chauvin, et. al. 2012). It has the highest share of food-insecure people, with 31.7% of the population (301 million people) food insecure in 2017 (United States Department of Agriculture, 2017). In sub-Saharan Africa (SSA), production on smallholder farms is critical to the food security of the rural poor (Herrero, *et al.*, 2010) and contributes the majority of food production at the national level. National policies and local interventions have profound impacts on the opportunities and constraints that affect smallholders. However, policy frameworks that aim to improve food security and rural livelihoods in the developing world face many uncertainties and often fail (Ericksen, *et. al.*, 2009). Nearly 240 million people in sub-Saharan Africa, or one person in every four, lack adequate food for a healthy and active life, and record/high food prices and drought are pushing more people into poverty and hunger (FAO, 2010).

Food insecurity in Sub-Saharan Africa, according to UN (2009), can be characterized by widespread chronic hunger, malnutrition as well as recurrent and acute food crises. Africa remains the region with the highest proportion of undernourished people (29 percent), compared to (17 percent), on average for developing countries. Over 70 percent of the food insecure population in Africa lives in rural areas. Smallholder farmers, the producers of over 90 percent of the continent’s food supply, make up half of this population. Improvements in agricultural production alone cannot address the malnutrition problem and unable to provide adequate food and nutrition without interventions to improve education, health, sanitation/care and feeding practices in the community. Innovative strategies that integrate agriculture and nutrition are essential and such nutrition-sensitive agricultural interventions can focus on how agricultural interventions in the field can be designed to improve nutritional outcomes whilst promoting livelihood security (Shetty, 2015).

The Region of the Horn of Africa includes (Ethiopia, Djibouti, Eritrea, Kenya, Somalia, Sudan and Uganda and is the poorest region on the continent. More than 40 per cent of the population of over 160 million is living in areas prone to extreme food shortages (FAO, 2011). Poverty and food insecurity in Ethiopia are mainly caused by poor performances of agriculture; and by poor policy and non-policy factors. Dependence on undiversified livelihood and low input/output and low technological base resulted in challenge to ensure food security (Demeke, *et.al*, 1995). Ethiopian farmers do not produce enough food, even in good rain fall years, to meet their consumption needs. Besides policies that focus on agricultural intensification, agriculture has misguided due to fragile natural resource base and climatic uncertainty. Inflexible land tenure is also one among the variety of issues which perpetuate challenges to ensure food security (Devereux, 2000).

The livelihoods of rural people are highly sensitive to climate. Food insecurity patterns are seasonal and linked to rainfall patterns, with hunger trends decline significantly after the rainy seasons. Climate related to shocks affect productivity, hamper economic progress, and exacerbate existing social and economic problems (Anderson, *et al.*, 2015). In Ethiopia, drought-initiated during the 1984/85 and 1989/90s resulted in production failures (Relief and Rehabilitation Commission/RRC, 1985). Drought in 1984/85 was the most serious, which was affecting over eight million people and causing the death of one million Ethiopians. Three years of successive poor rains in pastoral areas of the country was led to 100,000 deaths in 1999-2000; crisis years were also experienced in different parts of the country in 2003, 2008, 2011 and 2013 (DFID, 2014).

According to African Development Bank/ADB (2014), Ethiopia is one of the most food-insecure and famine affected countries. The larger portion of its population has affected by chronic and transitory food insecurity. Food security in Ethiopia is highly linked to recurring food shortage, which associates to recurrent drought. According to Bogale and Shimelis

(2009); FAO (2010); WFP and CSA (2014), more than 41% of Ethiopian people lives below poverty line and above 31 million were undernourished. Using the threshold 2,550 (Kcal) per adult equivalent per day, 40% of Ethiopian households, out of which the majority reside in rural areas of the country, were food insecure and undernourished. Food insecurity is an enduring, critical challenge in Ethiopia which is Africa's second populous country after Nigeria, where over 80 percent of Ethiopian live in rural areas and heavily depend on rain-fed agriculture that extremely vulnerable to weather changes (Andersson, *et. al*., 2009).

Food availability indicators, help to measure food availability at household level and is computed by adding food production, food storage, and purchases minus food sales (Kumar, 1989). According to Obamiro, *et. al.,* (2003); and Bonnard (1999), food availability can be analyzed through household surveys by assessing the volume of production, storage, sales, and purchases of food. Hence, food availability is a function of domestic food stocks and production. Domestic food production can be from crop production, animal production, fishing, or hunting and other sources for households' consumptions. Food security determinants, according to Rose, *et. al,* (1998); Mano, *et al*, (2003); Makombe, *et al*, (2011), can be various socio-economic, natural and political factors. Determinants can be income, education, age, availability of infrastructure, extension services, government policies, agricultural land area under cultivation, and social safety net program participation or not.

Food security has four dimensions that include availability, access, utilization and stability. To improve, availability/supply, the most important practice should be enhancing agricultural production through use of improved technologies and proper extension services. Increasing agricultural production is the base adequate supply, access, utilization and stability. To improve the availability (supply) of food at national regional and household level, use/adoption of improved technologies is the most important option. In food security, the food access dimension focuses on food distribution among household members, which can be realize only when there is food supply from different sources. Among different sources of food supply, production supply is the first and most important, especially for the faring community. The remaining food security dimensions, access, utilization and stability are the important dimensions of food security, but they are nothing unless, households ensure the availability (supply) of food. Since the concern of this study is the farming community, the farm households' need to ensure their adequate food availability through enhancing their agricultural production using/ or by adopting improved technologies.

2.2. Empirical Studies and evidences

2.2.1. Barley technologies adoption determinants

Agricultural technology adoption often varies from location to location. The variations in adoption proceed from the presence of disparities in agro-ecology, institutional and social factors (CIMMIYT, 1993). Farmers' adoption behavior, especially in low-income countries, has influenced by a complex set of socio-economic, demographic, technical, institutional and biophysical factors. Therefore, the direction and degree of impact of adoption determinants are not uniform that the impact varies depending on type of technology and the conditions of areas where the technology has been introduced (Legesse, 1998 and 2001). Practical experiences and observations of the reality have shown that, one factor may enhance adoption of one technology in one area for certain period, while it may create hindrance for other locations (Tesfaye, *et al.*, 2001). Because of these facts, it is difficult to develop a one and unified adoption model in technology adoption process for all locations (Abadi, 2014).

To understand the impacts and effects of factors affecting adoption of improved agricultural technologies, several studies have been undertaken. For example, Aman and Tefera (2016) have conducted a study to identify improved barley adoption intensity determinants in Malga district, Sidama Zone, Ethiopia using Tobit regression model. The Tobit model result revealed that age, farm experience, oxen ownership, membership of cooperative, distance to all weather roads and annual income were found significant affecting the intensity of barley technologies adoption. Another study conducted by Merga and Urgessa to analyze Determinants and Impacts of Modern Agricultural Technology Adoption in Gulliso District, West Wollega, Ethiopia, using Logistic regression model that the model result revealed the household heads' education level, farm size, credit accessibility, farmers' perception the inputs cost and off-farm income positively and significantly to affect the farm households' adoption decision; while family size affected their decision negatively and significantly.

Leake and Adam (2015) have undertaken the study to assess factors affecting the allocation of land for improved wheat by smallholder farmers of northern Ethiopia in Adwa district using Tobit model. The result revealed that adopters had high family size in adult-equivalent, high number of tropical livestock unit, large land size, high frequency of extension contact, access to credit service, formal schooling, and nearest to main road and market as compared to non-adopters. Out of the total of thirteen explanatory variables included in the model; only eight explanatory variables that include (education level of household head, family size, tropical livestock unit, and distance from main road and nearest market, access to credit service, extension contact and perception of the household towards cost of the technology) were the significant factors affecting adoption of improved wheat variety.

Merga and Urgessa (2014) carried out the study to analyze the determinants and impacts of modern agricultural technology adoption in Gulliso District, West Wollega Zone, Ethiopia. This study analyzed factors affecting modern agricultural technology adoption by farmers and the impact of technology adoption on the welfare of households. The binary logit model was used in study and the result of the logistic regression analysis showed that household heads' education level, farm size, credit accessibility, perception of farmers about cost of the inputs and off-farm income positively and significantly affected the farm households' adoption decision; while family size affected their decision negatively and significantly.

The study carried out by Abadi (2014) on the impact of improved maize varieties adoption on farmers' marketed maize surplus in *Oromia* region, Ethiopia. The study evaluated the impact of adoption of improved maize varieties on farmers' market participation in three *woreda*s of *Oromia* regional state. Both descriptive and econometric methods were used in the analysis. Descriptive analyses results have shown the existence of significant mean and proportion difference between adopters and non-adopters in terms of household head age, education, family size, livestock ownership, land holding, distance to main market, and accesses to output and input markets, access to extension services, and access to credit in favor of adopters. The results of the logit model showed that adoption of improved maize among households was found to be positively influenced by adult-literacy, family size, livestock wealth, access to output market and credit access for new varieties. On the other hand, farmer associations, distance to main markets and fertilizer credit influenced adoption negatively.

The study conducted by Beyan (2016), on Determinants in Smallholder Farmers' Decision to Adopt Multiple Cropping Technologies, in East Hararghe, Oromia, Ethiopia. The result showed, improvement of crop productivity through technologies adoption is for increasing output, reducing food insecurity and tackling land degradation. The study has examined factors influencing farmers' decision to adopt multiple cropping technologies. The estimation using multivariate probit model results indicated that variables affecting farmers' decisions to adopt a technology differ between technologies and adoption decisions are influenced by several factors such as family size, farming experience, social capital in the form of membership of rural institutions, credit constraint, education, livestock holding, access to technical support, farmers training, distance to markets, irrigation participation and distance to all-weather road. The result showed that the likelihoods of households to adopt soil conservation practices, improved seed, line planting and fertilizer were 79.6%, 69.6%, 61.2% and 70.5% respectively. It also showed that the joint probability of using all technologies was 22.8% and the joint probability of failure to adopt all technologies was 0.36%.

2.2.2. Determinants of farm households' perception towards extension services

Agricultural extension, being a specialized form of adult education, is an educational process, which is mainly a communication process between extension agents and rural dwellers. It is very useful for involving rural dwellers in agricultural development to teach them better farming practices with the aim of increasing productivity and enhance their standard of living (Adeokun, *et. al.*, 2006). Furthermore, agricultural extension service is to provide agricultural services such as agricultural input supply, credit access, access to agricultural agents, improving knowledge and attitude of farmers towards extension services. Providing agricultural and rural services such as agricultural extension is essential in using agriculture for development (Asante and Ntow, 2009).

Assessment of farm households' perception towards agricultural extension service and its roles to improve adoption of barley technologies, thereby, income and food availability of farm households was conducted. Before conducting the farm households' perception assessment, assessment of previous research findings was conducted. As a result, farmers' perceptions on the quality of extension services provided by non-governmental organizations in two municipalities of the Central Region of Ghana was conducted by Buadihe, *et, al,* (2013) to reach at the conclusion that farmers perceived the extension services provided by the non-governmental organizations in two municipalities of the Central Region of Ghana were relevant to their farming. Another study was conducted by Ibrahim, et. al., (2014), to determine the perception of farmers on extension services in Kano state of Nigeria,) using descriptive statistics, and Likert scale that results revealed, farmers based on their perception, ranked radio as the first extension method, followed by farm and home visit.

Furthermore, Rathod, *et.al*, (2012) were conducted on farmers' perception towards livestock extension in Western Maharashtra region to know farmers' perception towards livestock extension services delivered by dairy cooperatives, especially with regards to timely availability. The result of the study showed that 56% of farmers perceived the cooperative dairy extension services were available on time. Farmers' perception and adoption of agroforestry in Osun state, Nigeria was assessed by Adedayo and Oluronke in (2014). The result of the study showed that there were divergent perceptions among farmers about agroforestry practice that 10% of the respondents in Osun west senatorial district perceived agroforestry practice is a scientific process that is difficult to practice by the farmers, 62% perceived that it can improve farm productivity, while 12% perceived that the practice is not properly understood. Another study conducted on farmers' perception regarding their perception towards climate change and adaptation in the Nile basin of Ethiopia by Deressa, *et. al.,* (2010) using Heckman probit model. The model result revealed that age of the head, farm income, information, farm-to-farm extension, number of relatives in a Got and agro-ecological settings affected the farmers' perception towards climate change positively.

The study by Uddin, *et. al.,* (20017) on the Determinants of Farmers' Perception on Climate Change, which was a Case Study from Coastal Region of Bangladesh was conducted and the analysis was carried out using the Logit model and the result showed that, out of nine factors; education (+), family size (-), farm size (-), family income (+), farming experiences (+) and training received (+) were significantly affecting farmers' perception of climate change. Two predictors (farm size and family size) have affected negatively; while the rest predictors were affected farmers' perception positively. Another study conducted on Farmers' perceptions and adaptation strategies to climate change and their determinants in Punjab province, Pakistan (Abid, et. al., 2015), logit model results, revealed that education, farm experience, household size, land area, tenancy status, ownership of a tube well, market information, weather forecasting information and extension services influence farmers' choices of adaptation measures. The results also indicate that adaptation to climate change is constrained by several factors such as lack of information, lack of money, resource constraints and shortage of irrigation water in the study area.

The Econometric analysis of local level perception, adaptation and coping strategies to climate change induced shocks in North *Shewa*, Ethiopia, was conducted by Gutu, *et. al.,* (2012) using Heckman sample selection equation that the result of the analysis revealed that access to awareness raising meetings regarding climate change and natural environment issues, knowledge of indigenous early warning information, access to formal early warning information, frequency of contact with agricultural extension agents, educational level of household head and age of the household head showed positive and significant effect on perception of farmers towards climate change; while Distant from output market and input market, Female headed households, *Woinadega* (midland) and *Dega* (highlands) farmers show negative effect on climate change perception of farm households.

The study on Farmers' Perception on The Value of Commercialized Agricultural Extension System in Delta State, Nigeria by Onyemekihian, *et. al,* (2017). The result of multiple regression revealed that age (+), farming experience (+), sex (-) and income (-) were significant factors affecting farmers' value for a commercialized extension system. Another study on the Determinants of Farmers' Perceptions towards Adoption of New Farming Techniques in Paddy Production in Sri Lanka, conducted by Karunathilaka and Thayaparan (2016) using Tobit Regression model that the model result revealed that farmers' age (+), education (+), size of cultivated land (+), ownership of land (-), farming experience (+), attitudes of the farmers towards the risk (-) and availability of market information (+) affected the perception of farmers towards the adoption of new farming techniques.

2.2.3. Farm households' income determinants

The study by Ibrahim, et. al., (2013), conducted to determine the income sources among paddy farmers in *Muda* irrigation area, Malaysia. The result of the study showed that agricultural income accounted for 73.6% of the total income of paddy farmers in *Muda* irrigation area; while side income accounted for 9.23%, non-agricultural income accounted for 12.47% and other income accounted for 4.45% of the total income of the paddy farmers. The double log regression analysis, showed that the ownership of lands, land rent, non-agricultural income, subsidy recipients, education level, and number of part time job have a significant result which were the positive relationships towards the income sources of paddy farmers. Another study by Nzabakenga, *et. al.*, (2013) was conducted in northern part of Burundi to analyze the agricultural income determinants among smallholder farmers using linear regression. The study was found that among the eight (8) predictors, family size and farm size showed significant effects on agricultural income. Some suggestions were also mentioned to sustain agricultural returns, the well-being of farm households and to improve rural infrastructure.

Analysis of determinants of Poverty Incidence among Rural Farmers in Ondo State, Nigeria was conducted by Igbalajobi, *et. al*, (2013). The study used descriptive statistics, Foster-Greer-Thorbecke (FGT) poverty measure, Gini coefficient and probit regression analysis. The result has revealed that 59.3% of the respondents were actually poor. The descriptive analysis showed that based on the value of poverty line (580.42 USD) per annum, about 60% of households earn less than the value of poverty line was considered to be poor, while those that earn greater than and equal to the value of poverty line were considered to be non-poor which is 40.7% of sampled households. This implies that the majority of respondents live below the average income in the study area. The result of Gini coefficient (0.492) implies the average level of income inequality among respondents; and the Probit regression model result indicated that age, marital status, gender, farm income, household size, access to credit, and educational level were statistically significant in alleviating poverty in the study area.

The study conducted by Birthal, *et. al.*, (2014), on income sources of farm households in India: determinants, distributional consequences and policy implications. The study examined farm households' access to different income sources, and their impact on income distribution. The analysis showed against the common perception of agriculture being the dominant income source for farm households who earn close to half of their income from non-farm activities, which are more important for households at lower end of land distribution. Poor households diversify towards low-paid, low-return non-farm activities. Small landholdings, low agricultural productivity and surplus labor force farm households to diversify their income portfolio towards non-farm activities. The non-farm income sources are accessible to a small proportion of farm households and have un-equalizing effect on income distribution.

The study conducted on determinants of rural poverty in Africa on Yam Farm Households in South Eastern Nigeria by Ogbonna, *et. al*, (2014) showed determinants affecting households to exit from poverty. The analysis was conducted using poverty ratios and regression. The poverty line for the poor yam household heads was established as N678.59 (in Nigerian money) per person per day; while the mean household size and amount spent per person were 6 persons and N113.10 respectively. The analysis result revealed that determinants of poverty were level of education which has negative sign and significant at 5%, membership of farmer's group was negative and significant at 10% while yam production experience was negative and significant at 1% and participation in agricultural workshop was negative and significant at 5%. These factors significantly decreased poverty; while that of household dependency ratio was positive and significant at 1% but increased poverty.

In spite of the various poverty alleviation programs embarked/upon/begin by the Nigerian government to reduce poverty, a large proportion of the populace remain poor. This study was therefore carried out to evaluate the determinants of income among rural households in Kwara State, Nigeria. Descriptive statistics and the multiple regression analysis were the major analytical tools employed for the study. The result of the analysis showed that farm income is the most important source of income for rural households in the study area making up 57.9% of total household income. Level of education of the household head, farm size and access to electricity and gender of the household head were identified as the major determinant of household income in the study area. The study recommends that these income determinants should be carefully integrated in rural development policies in order to improve the rural household's purchasing power as well as the income distribution in the study area.

The study on determinants of income among farm households conducted by Ibekwew, (2010) in Orlu Agricultural Zone of Imo State, Nigeria to provide an environment that will stimulate growth and ensure equitable income distribution that needs careful study of income determinants to be used in carefully tailored/fitted policies. This study determined an average farm household income of N60, 197.81 per annum, N7, 524.73 a per capita income, and a Gini-coefficient of 0.488. The income regression parameter estimates showed that variables, extension services, property income and farm size were positively correlated with farm household income and were significant at 5% level. It is suggested that a careful integration of these income determinants in rural development policies will no doubt to improve farm households' purchasing power and the income distribution in the study area. The study that was focused on rural households' income determinants analysis in the post-liberalization era in Bangladesh was conducted by Talukder (2014). The study applied the ordinary least square (OLS) model. The (OLS) result revealed that household size was the only non-economic factor that was statistically significant and positive determinant of household income. Considering initial endowments, household land was the largest positive determinant and share of income from wage-salary was the largest negative determinant of income-growth.

The study conducted by Busha, *et.al*, (2015) on the contribution of dry forest to households' income and its determinants in North western and Southern Low lands of Ethiopia were conducted using regression analysis, one-way ANOVA, chi-square and t-tests. The major sources of households' income were crop, livestock, forest products, off-farm and non-farm activities, remittances and aids. The regression analysis revealed that the percentage of the population living below poverty line (set at 3,781 birr/adult/year) has declined from 45.50% in 1995/96 to 29.6% in 2010/11 with poverty more prevalent in rural areas. The percentage of chronically malnourished/stunted children dropped from 58% in 2000 to 44% in 2011 (DHS, 2011). The poverty line measure includes not only the cost of the minimum calories required by the household, but also a specific allowance for non-food goods consistent with the spending of the poor. Based on poverty line for 2010/11 that stands at 3,781 Ethiopian Birr, the study report by CSA and WFP (2014) has shown that in Ethiopia, 23% of households nationally are below the absolute poverty line (24% rural and 19% urban).

The econometric analysis conducted by Schwarze (2004) on Determinants of Income Generating Activities of Rural Households using a linear regression model that the result revealed, access to physical and human capital has a significant influence on total household income. Furthermore, land size owned, the value of other assets possessed, and the number of livestock owned have shown positive influence on the total income of the household. Furthermore, the dependency ratio has a negative influence. The study conducted by Yisihake and Abebe (2015) to Assessing Determinant Factors of Income Diversification among Rural Farm Households in Ethiopia: The Case of Leemo and Anileemo Districts, Hadiya Zone, South Nation Nationalities People Region. The study was used multiple regression model to analyze determinants of the number of income diversification sources among rural farm households, the significant variables were sex of household head (+), education level of household head (+), farm size (-), farm income (-) and distance to market center (+).

The study conducted by Yishak (2017) on Rural Farm Households' Income Diversification in Wolaita Zone, Southern Ethiopia using Logit regression model. The model result revealed that sex (-) education (+), oxen ownership (-), tropical livestock (-), farm size (-), distance to market (-), participation in local leadership (+) and annual total farm income (-) were significant with the indicated or attached sign in affecting the income diversification of farmers. Another study on the Determinants of Income and Income Gap between Urban and Rural Pakistan by Ali and ZekeriyaNas (2013) by applying the Ordinary Least Squares (OLS) method that the OLS estimate revealed literacy, education and occupation have emerged as the major determinants of income and its gap between urban and rural Pakistan.

Several empirical studies showed that the farm households' income level has affected by several factors that can be grouped into demographic factors such as (age, education, family size, sex), and by resource and economic factors such as (land ownership, livestock ownership, off-farm activities), by infrastructure services such (market distance, road), by institutional factors such as (extension service, credit service, input supply), which affecting the farm households' income. In some study, these predictors affect positively and significantly, while in the other studies negatively and significantly, and in some other studies, they do not show any significance effect on the dependent variable, households' income. In this study, these predictors were also use and the results of the analysis showed in the section of farm households' income determinants.

2.2.4. Farm households' food availability determinants

Food security is a complex, multifactorial issue referring to a reliable access to sufficient food incorporating availability, access, utilization and stability (FAO, 2006; FAO, 2008; and Innes-Hughes, *et. al.*, 2010); while food insecurity arises when access is restricted/uncertain (FAO, 2003). Food security is an important issue for both developed and un-developed countries, but, in developing countries, the situation is more severe. According to FAO (2015), out of 795 million people are suffering from hunger, out of which, 780 million live in developing countries. In the world, 925 million people are undernourished. Out of which, about 900 million are living in developing countries; and more than 70% live in rural areas and depend, directly/indirectly on agriculture for their living (FAO, 2010). Enough quantity and quality food is required for all people and for nations to continue development. Lack of food in long terms will lead to hunger and starvation that can cause death. So, availability of enough food is a necessary condition for humans' survival (Sila and Pellokila, 2007).

According to FAO (2014) in food availability assessment, the quantity, quality and diversity are important indicators that need to be included as dietary energy supply, the share of calories from cereals, roots, tubers, the protein supply animal-source proteins, and the value of food production, water availability, market and infrastructure. Availability of sufficient food refers to the overall ability of agricultural system to meet food demand through production (Schmidhuber and Tubiello, 2007); and it is achieved if adequate food is ready at people's disposal (Gross 2000). Food availability addresses the supply side of food security and determined by the production level, stock levels and net trade. There are several studies in food availability and in food access. In all dimensions, food security determinants, which almost all showed the deficiency, quality and varieties affected by different factors that need immediate policy and development interventions.

The study, conducted by Fekede, *et. al,* (2016) in Hawi Gudina district, West Hararghe, Oromia, Ethiopia, on determinants of farm HHs' food security. The logit model was employed and the analysis result revealed that high livestock ownership, access to non-farm activity and producing cash crops affected food security positively and significantly; while large family size and distance from market center have affected the household food security status negatively. Another study conducted by Joshi and Joshi (2017) in mountainous districts of Nepal on Household food security Trends and determinants using binary logit regression model that the model analysis output showed that the households' food security was positively affected by male-headed household, household members with both agricultural and allied occupation, age of the household head, percentage of irrigated area, number of livestock owned by the household, and owner operator; while household size, time taken to reach the nearest market have affected household food security status negatively.

The study conducted by Akinboade, *et. al.,* (2016), to identify Determinants of Food Insecurity among Urban Poor in the City of Tshwane, South Africa using logistic regression model. The model result showed that, while some degree of food security exists in the study areas, this could be boosted by increasing income, education and employment of HHs. As the HHs' size increases, especially of children below five years' age, coupled with relying on help from others, household's food security showed to decrease. Another study conducted by Tesfay, *et. al.,* (2014) to assess the Urban food insecurity in the context of high food prices using cross sectional data in Addis Ababa, Ethiopia. The Logit model was used and its output revealed that household's income, asset possession, house ownership, education, employment and family size showed significant association with food security of the HHs. Furthermore, lower monthly income, uneducated household head, daily laborers, and government employees were more likely to have higher food insecurity., households living in government rental houses were less likely to be food insecure, as compared to other residential houses.

The study conducted by Shiferaw, *et. al.,* (2003) using logit regression model to identify food security determinants in Southern Ethiopia, the model analysis result revealed that technology adoption, cereal-based farming system than cereal-enset-based farming system, farm size, land quality; while household size, per capita aggregate production, and access to market affected negatively. Food availability determinants were also assessed in Ghana by Adom (2014) using multiple regression model that the results showed that (energy price, domestic and foreign interest rates, domestic prices and exchange rate) showed negative and significant effect on food availability; while (crop yield, arable land, liberalization of agricultural trade and real income) showed positive effect on households' food availability.

The study conducted by Kidane, *et. al*, (2005) to examine determinants of households' food security using logistic regression model. The model result revealed that farmland size, oxen ownership, fertilizer use, education level of HH heads, HH size, and per capita production were affected household's food security status significantly. Among which, except household size, all significant variables were affecting the dependent variable household food security status positively. Another study conducted by Tekle and Berhanu (2015) using logit model. The logit result revealed that age of the household head, family size and access to extension services had a negative effect; while the household income, credit access, oxen ownership and cultivable land size had a positive effect on household food security.

The study conducted by Jabo, *et. al.,* (2017) on measurement and determinants of rural food poverty in Nigeria based on recent evidence from general household survey pane/sheet. The study used logit regression model to determine factors affecting households' food security. The results of the study revealed that household head age (-), tertiary education (+), farm size (+), household size (-), value of livestock holdings (+), remittances received, participation in nonfarm enterprise and access to formal credit (+) have significant impact on food security. Another study conducted by Okon, *et. al,* (2017) using logit model on Household level food security status and its determinants among rural farmers in Akwa Ibom State, Nigeria using. The model result revealed that among predictors, household heads' educational levels (+), marital status (+), household size (-), use of chemical fertilizer (+), soil conservation practices (+) and dependency ratio (-) have affected the household food availability status significantly with the associated/indicated sign to each of the significant predictors.

The study conducted by Ahmed, *et. al.*, (2017) on small farming households' food security status and determinants and on market access role in enhancing food security in rural Pakistan using logistic model that its result revealed family size (-), monthly income (+), food prices (-), health expenses (-), debt (-), market accessibility (+), road distance (-) and transportation cost (-) affected significantly the small farming households' food security status. Another study conducted by Darsono (2017) on Staple Food Self-Sufficiency of Farmers in the Great Solo using ordinary least square regression (OLS). The OLS analysis result revealed that rice production (+), rice consumption (-), land tenure (+), and number of family members (-) affected the food self-sufficiency of farm household, significantly.

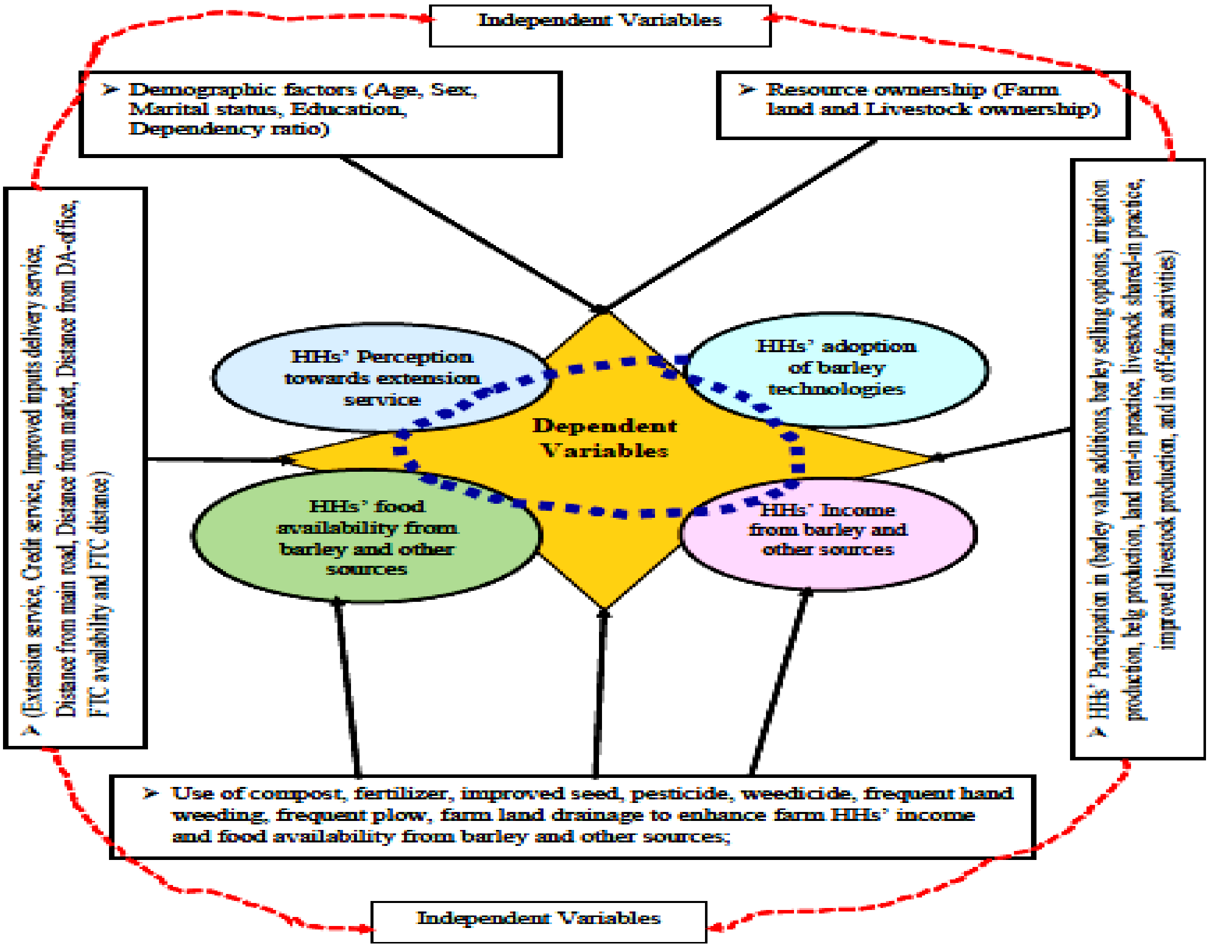
Many of empirical studies showed that farm households' food security has affected by different factors grouped into demographic factors such as (age, education, family size, sex), and by resource and economic factors such as (land ownership, livestock ownership, off-farm activities), by infrastructure services such (market distance, road), by institutional factors such as (extension service, credit service, input supply such as fertilizer, improved seed, etc). These explanatory variables showed to affect the farm households' food security status that in some studies, they affect positively and significantly, in other studies negatively and significantly, and still in some in some other studies, they do not show any significance value. In this study, the predictors that were hypothesized to affect the proposed dependent variables proposed were also used and the results of the analysis showed and presented in the section of farm households' food availability determinants.

2.2.5. Conceptual framework of the study

Conceptual framework is interconnected/or interrelated parts/ or sets of ideas regarding the particular phenomenon and shows how parts are functioning (Svinicki, 2010). It lays out the key factors, constructs, or variables, and relationships among them. Conceptual framework contributes to better research and helps researchers to clarify their thoughts (Miles and Huberman, 1994). Therefore, the conceptual frame work for this study has developed based on the review of related literatures and previous research outputs with the current study. Accordingly, the conceptual framework for this study has outlined as indicated in Figure 3 that shows the key predictors and outcome variables and their relationships.

The interactions among (dependent and independent) variables affect the highland barley farm households' well-being and livelihood statuses. As indicated in the Figure 3, independent variables used in this study are summarized and grouped in to demographic characteristics (age, sex, education, household size, marital status and dependency ratio), in to economic resources (ownership/farm land size in Ha and livestock size in TLU). Institutional factors (credit, extension, and input supply services), infrastructures (market distance, main road, DA-office, inputs and credit supply center, and FTC).

Figure 3. Conceptual frame work of the study



Source: own development

The other, predictors indicated in the conceptual framework, include farm households' participation in barley value additions, in irrigation and *Belg* production, land rent-in and livestock shared-in practices, in off-farm activities, in improved livestock production. Then, the conceptual framework comprises the dependent and independent variables used in the analyses and it represents the interaction and results of the interaction among variables.

CHAPTER THREE: RESEARCH METHODS AND DESCRIPTION OF THE STUDY AREAS

3.1. Description of the study areas

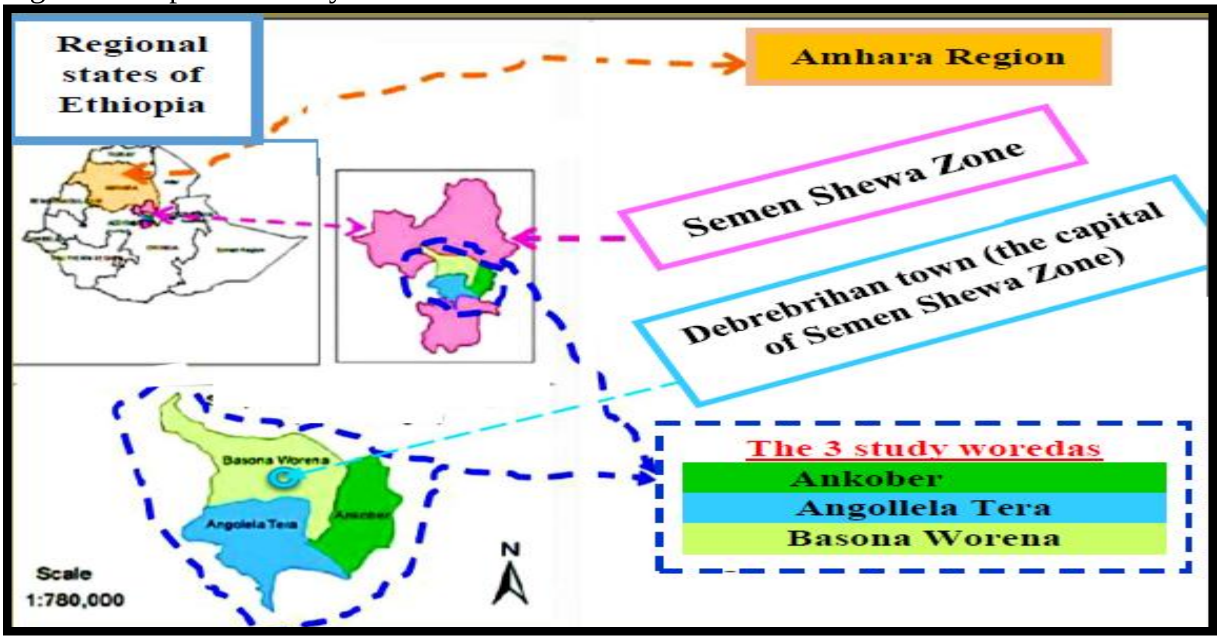
The current study on barley technologies adoption and its contribution to farm households' income and food availability was conducted in three *woredas*, namely in *Ankober, Angollela and Basaona*, located in *Semen Shewa* Zone, Amhara Region, central highlands of Ethiopia. For this study, nine rural *Kebeles* were randomly selected among the potentially barley producing rural *kebeles.* The selected rural *kebeles* include *(Ligoregela, Chefana,* and *Derefo)* from *Ankober woreda, (Debele, Dibut, and Gudoberet)* from *Basona woreda,* and *(Tsigereda, Bura and Asaberet*) rural *kebeles* from *Angollela woreda.* From each study *woreda,* three rural *kebeles,* a total of nine rural from the three study *worredas* were selected. *Semen Shewa* Zone, from which the study *woredas* were selected is one of the administration Zones in Amhara region, which is one of the Regional states in Ethiopia.

The total *woredas* in the Zone are 23 that include (*Angolalla, Ankober, Antsokiyana-Gemza, Asagirt, Basona, Berehet, Efratana-Gidim, Ensaro, Geshebado, Hagere-Mariamna-Kesem, Kewet, Menjarna-Shenkora, Menz-Gera-Midir, Menz-Keya-Gebreal, Menz-Lalo-Midir, Menz-Mam-Midir, Merhabiete, Mida-Woremo, Mojona-Wadera, Moretna-Jiru, Siyadebrina-Wayu, Termabera,* and *Debre-Berhan,* which is the Zone administrative center (NSZADO, 2012). Out of which, the three *woredas,* which covered 13% of the total *woredas* in the Zone were selected for this study.

The Map of the study area, as shown in the Figure 4, indicates the regional states of the country (Ethiopia), the *Amhara* region, *Semen Shewa* Zone, and the three study *woredas (Ankober, Basona* and *Angollela)* were selected purposively for this study based on their barley production potentials, their proximity to, road access and by taking in to account the research budget adequacy. From each study *woreda*, three rural *kebeles* known in their barley production were selected randomly for cross sectional survey data collection. Before selection of the study *kebeles,* first, the rural *kebeles* in each study *woreda* were classified in to barley potential and non-potential *kebeles*. Then, from those barley potential producer

Kebeles, three *kebeles* from each study *woreda* were selected randomly. Hence, for this study, a total of nine barley-potential producers rural *kebeles*, were selected randomly.

Figure 4. Map of the study area



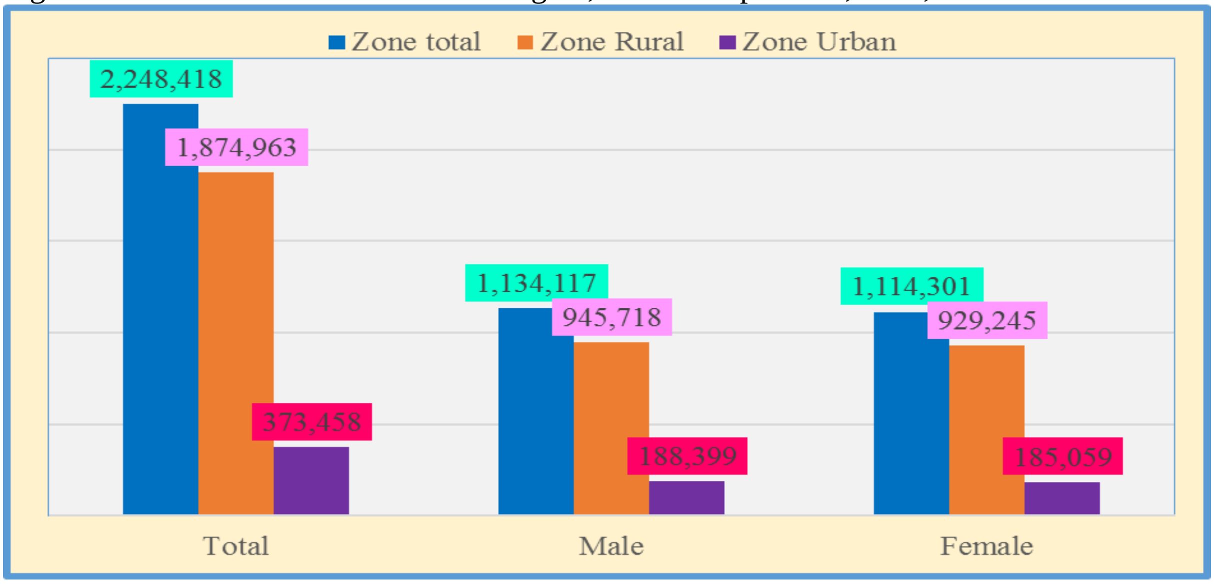
Map of Ethiopia, Amhara Region, Semen Shewa Zone, *Ankober, Angollela* and *Basona woredas* showing the study area

The common boundaries of the Zone include, with *Oromia* Region in South and South West, with South *Wollo* Zone (one of the Zones in *Amhara* region), in North and with Afar region in the East. Its topography comprises uneven and ragged mountainous highlands, extensive plains and deep gorges and cliffs (Zelalem, 2001).

The rainfall of the Zone has been characterized by a bimodal distribution with the major rainy season *Kiremt* for *meher* production (June-August) and the short rainy season '*Belg*'(March-May). The big harvest is the *Meher* using the *Kiremt* rainfall (the main rainy season), and the low harvest is during the *Belg* production season using the small rains. The rainfall amount of the Zone, per annum ranges between (800-1500 mm), and the annual temperature ranges from 6°C to 20°C (Ahmed, 2010; NSZADO, 2012; and CSA, 2012/13).

In *Semen Shewa* Zone, based on CSA population projection for 2017, the total population including rural and urban dwellers as shown in Figure 4 was 2, 248, 418. Among which, the male population was 1, 134, 117, which include 945, 718 rural and 188, 399 urban; and the female population was 1,114, 301 that include 929, 245 rural and 185, 059 urban population. The total rural population was 1, 874, 963 and that of urban population was 373,458.

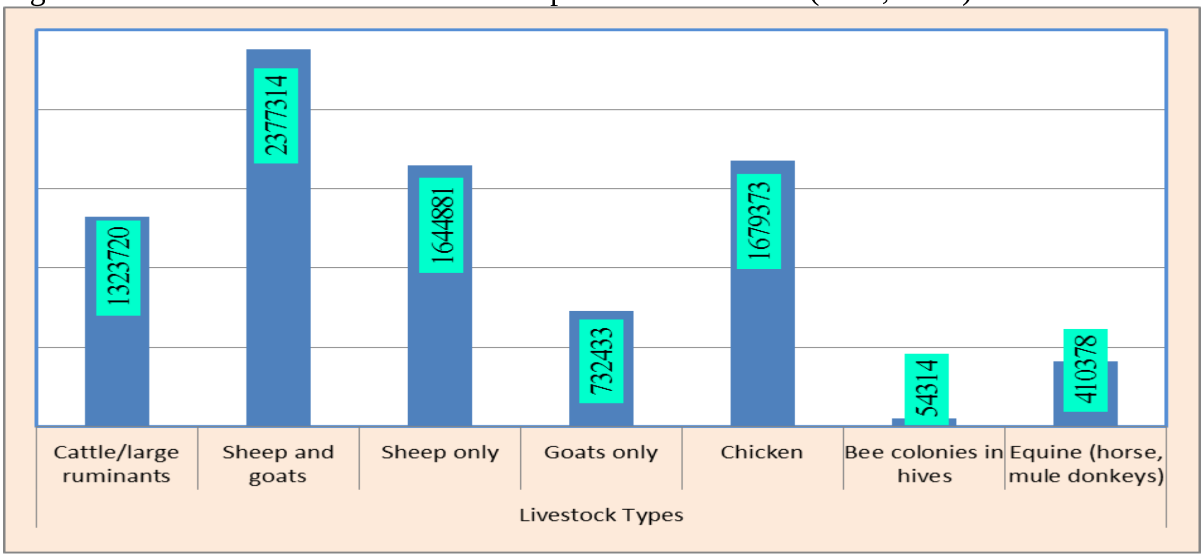
Figure 5. *Semen Shewa* Zone/Amhara Region, Human Population, CSA, 2017 Data



Source: own organization from CSA 2017 population projection

Regarding the livestock population of the Zone as taken from (CSA), projection for 2017 as summarized in the Figure 5, the sheep and goat population in number was 2, 377, 314, which is the largest population. Out of which, the sheep population was estimated as 1,644,881 and that of goats population was 732, 433, which showed that in the study area, the sheep population is much higher. The chicken population was the second in number that followed by cattle population (1323720) in number. The population of equine that include horse, donkey and mule) and Bee colony in hive also indicated in the Figure5.

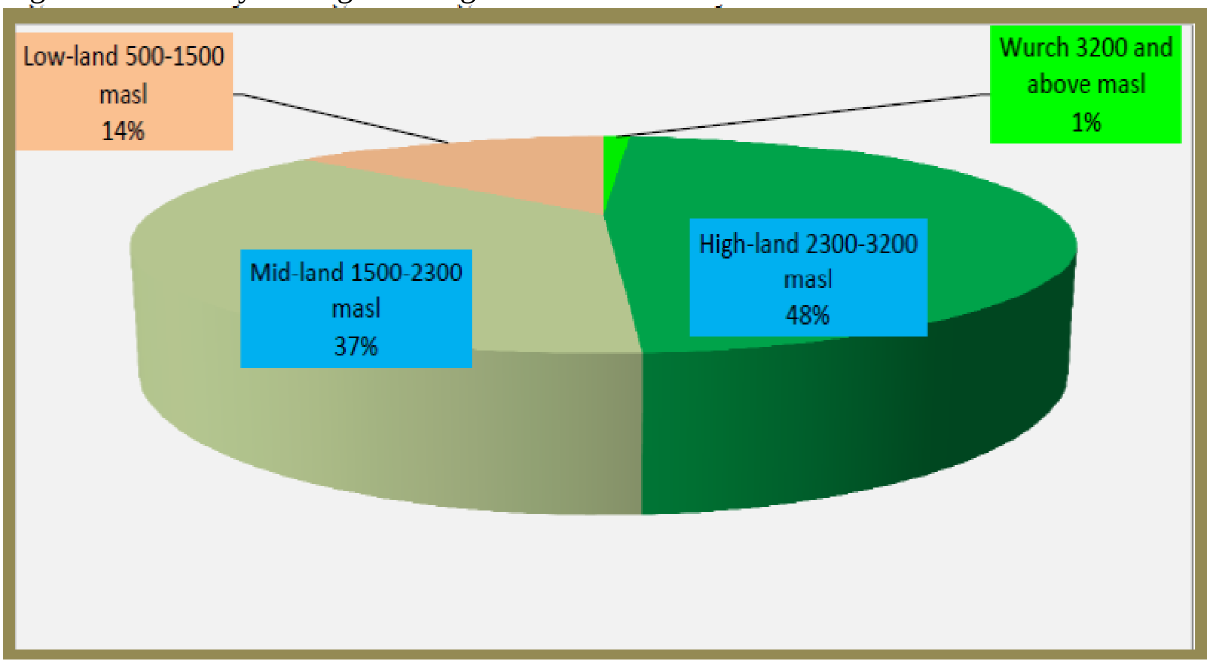
Figure 6. *Semen Shewa Zone* Livestock Population in Number (CSA, 2017) Data



Source: CSA (2017)

Regarding the Agro-ecological classification of the study *woreda* as indicated in the Figure 7 Based on the agro-ecological classification that include low land that covers 500-1500 masl; mid-land 1500-2300 masl; highland 2300-3200 masl; and *Wurch*/frost 3200 masl and above, the study area agro-ecological classification includes (low land 14%, mid-land 37%, highland 48%; and 1% covers *Wurch*/frost zone).

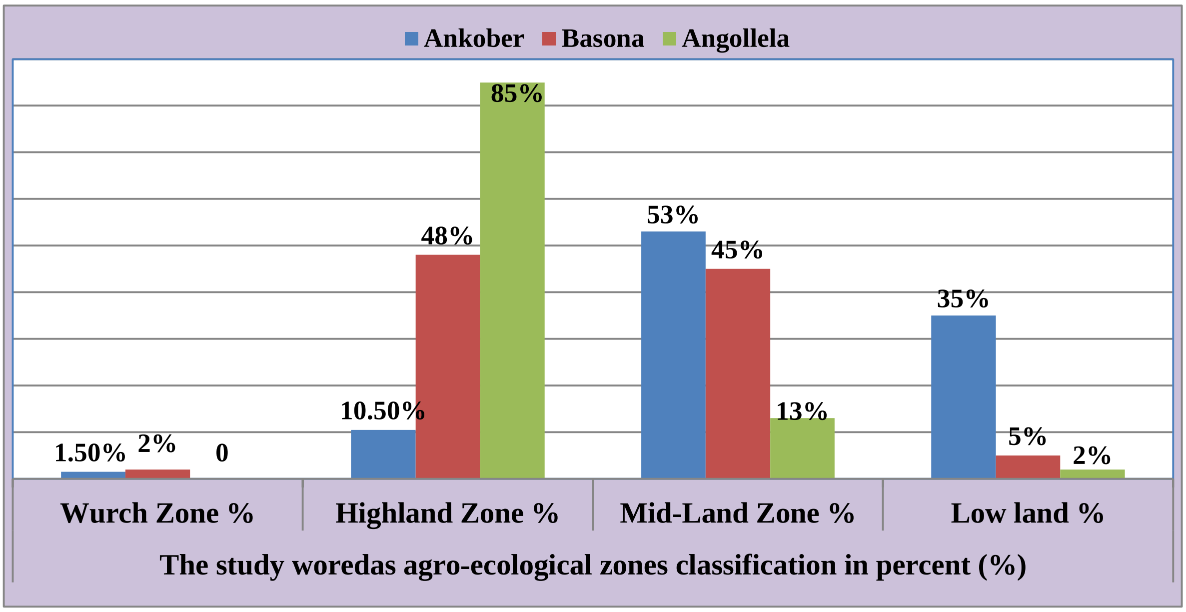
Figure 7. The study area agro-ecological zones



Source: The study *woredas* office of agriculture

The highland agro-ecological zone coverage of the Zone is wider that followed by mid-land, and low land, although the *Wurch* ecological zone has very low coverage closer to 1%, as indicated in Figure 6. Regarding the ecological coverage distribution by the study *woreda,* the coverage of *wurch* in *Ankober* and *Basona* is 1.5% and 2% respectively; but no *wurch* agro-ecological zone in *Angollela woreda* as indicated in the Figure 7 that showed the agro-ecological Zone classification and distribution by in each study *woreda (Ankober, Basona* and *Angollela).* The high land ecological coverage is wider in *Angollela woreda* as compared to *Ankober* and *Basona woreda. Ankober woreda* has wider coverage in its mid-land ecological zone as compared to *Angollela* and *Basona woredas* as indicated in the Figure 8. Geographically, *Ankober wpreda* is located on the eastern escarpment of the Ethiopian highlands at 172 km north of Addis Ababa and 42 km to the east of *Debreberhan* town.

Figure 8. The study area agro-ecological Zone classification b y the study woreda



Source: The study *woredas* office of agriculture (*Ankober*, *Angollela*, and *Basona woreda*) 2014/2015

The *woreda* is bordered in North by *Tarmaber,* in south by *Asagirt,* in the west by *Basona woreda* of Semen Shewa Zone/Amhara Region. The eastern part of *Ankober* shares its border with *Gachine,* special *woreda* of Afar Region. The elevation of the *woreda* ranges from 1300-3700 m.a.s.l. Its total land area is estimated to be 199,342 hectares. Its annual rainfall ranges from 1000-1400 mm and cold in temperature in most of the year. *Gorebela* is the town and the administrative center for *Ankober woreda*. It has a historical significance as it has been the seat of the Ethiopian emperors since 1270 for centuries (NSZADO, 2012).

On the other hand, *Basona woreda*, which is one of the study *woreda* is located at the eastern edge of the Ethiopian highlands. The *woreda* is bordered on south by *Angolalla woreda,* on the west by *Siyadebrina-wayu woreda*, and on northwest by *Moretna-jiru woreda* of *Semen Shewa* Zone (*Amhara*). The *woreda* also bordered by *Mojana-wadera* on the north. *Basona woreda* again bordered by *Tarmaber woreda* on the northeast; by *Ankober woreda*, on the eastern direction of Semen *Shewa* Zone/*Amhara*; and by *Oromia* Region on the Southwest direction. The total land area of *Basona woreda* is estimated to be 142,082 hectares and its altitude is between 1500-3400 m.a.s.l. *Debreberhan* town, which is one of the *woredas* of *Semen Shewa* Zone, and the center for *Basona woreda* is enclave inside *Basona woreda*. *Angollela woreda* is the third *woreda* selected for this study is located at the eastern edge of Ethiopian highlands. *Angollela woreda* is bordered on the south west by *Hagere Mariamna Kesem woreda*, on the north by *Basona woreda*, on the northeast by *Ankober woreda,* and on the southeast by *Berehet woreda* and *Asagirt woredas* of the Zone; and on the west by Oromia Region. Its altitude is in between 1700-3245 *m.a.s.l*. The total land area of *Angollela woreda* is estimated to be 98, 990 (Ha). *Chacha* is the town and administrative center for *Angollela woreda* (NSZADO, 2012).

In the study area, in (*Ankober, Basona,* and *Angollela woreda*), the human population and its distribution by household sex and by *woreda* has summarized in the Table 1. The population size was taken from CSA population projection for 2017 (CSA, 2013/2014). Therefore, in the study area, out of the total population of the three study *woredas* (329,753), (50.65%) were male and (49.35%) were female, which shows that the male and female population is almost equal. As indicated in the Table 1 the population distribution of each study *woreda* and its percentage has shown by calculated from the total population. As a result, the population in *Ankober woreda* was (27.58%), in *Basona* (42.57%), and in *Angollela* (29. 85%), which revealed that population in *Basona woreda* was high than the two *woreda*s.

Table 1. Population distribution by the study *woredas*

The study area human population	Ankober	Basona	Angollela	Total
Total population	90,949 (27.58)	140,386 (42.57)	98,418 (29.85)	329,753 (100)
Male	45,852 (50.42)	71,439 (50.89)	49,741(50.54)	167,032 (50.65)
Female	45,097 (49.58)	68,947 (49.11)	48,677 (49.46)	162,721 (49.35)
Urban population	7,664 (39.08)	2,122 (10.82)	9,824 (50.10)	19,610 (100)
Male	3,679 (48)	1,019 (48.02)	4,724 (48.09)	9,422 (48.05)
Female	3,985 (52)	1,103 (51.98)	5,100 (51.91)	10,188 (51.95)
Rural population	83,285 (26.85)	138,264 (44.58)	88,594 (28.57)	310,143 (100)
Male	42,173 (50.64)	70,420 (50.93)	45,017 (50.81)	157,610 (50.65)
Female	41,112 (49.36)	67,844 (49.07)	43,577 (49.19)	152,533 (49.35)

Source: CSA population projection for 2017 (CSA, 2012/13);and numbers in parentheses represent percent

The *woreda* distribution of the population showed that higher population is found in *Basona woreda* as compared to the other two *woredas, Ankober* and *Angollela.* Regarding the rural and urban population in the study area, out of (329,753) total population, 19,610 (6%) is the urban population and the rest 310,143 (94%) are the rural population. Therefore, most of the population in the study area are rural dwellers. In the study area (*Ankober, Basona* and *Angollela) woreda,* the livestock types reared by the farm households include (cattle, sheep and goat, chicken/poultry, equine/pack animals such as horse, mule and donkey, and honey bee). As indicated in the Table 2, the livestock population distribution of the study area showed that, cattle population in *Angollela woreda* (41.66%) is higher as compared to in *Basona* (34.73%) and *Ankober woredas* (23. 61%). The sheep and goat population is less in *Ankober woreda* (25.48%) than in *Basona woreda* (37.95%) and in *Angollela woreda* (36.57%). The chicken population showed that, the highest population is found in *Basona woreda* (42.26%), followed by *Angollela* (35.16%) and *Ankober woreda* (22.58%).

Table 2. Livestock population of the study area (*Ankober*, *Badsona* and *Angollela*)

Livestock Types	Ankober	Basona	Angollela	Livestock population
Total Cattle population	62,940 (23.61)	92,592 (34.73)	111,061 (41.66)	266, 593
Total Sheep and Goats population	90,215 (25.48)	134,381 (37.95)	129,480 (36.57)	354,076
Total Chicken population	62,300 (22.58)	116, 629 (42.26)	97,019 (35.16)	275,948
Equines/pack animals population	10,456 (12.33)	31, 884 (37.61)	42, 429 (50.05)	84,769
Total Honey-bee colonies in hives	5,518 (41.11)	6, 146 (45.79)	1,758 (13.10)	13,422

Source: Organized from the study *woreda* offices of agriculture (*Ankober, Basona*, and *Angollela woreda*); and numbers in parentheses represent percent

The equine/pack animals' population that include (Horse, mule, and donkey), as shown in the Table 2, the higher population is found in *Angollela* (50.05%) and in *Basona* (37.61%), but low population in *Ankober woreda* (12.33%). Concerning the population of honey bee colonies that counted in hives, out of (13,422) total bee colonies in hive, (45.79%) is found in *Basona*, (41.11%) in *Ankober*, and (13.10%) in *Angollela woreda*. Hence, the less population of bee colonies in hive is found in *Angollela woreda* as compared to *Basona* and *Ankober woredas*. The benefits farm households get from livestock include milk and milk products (cheese and butter), meat, egg, honey and honey wax; transport and power for farm land plowing of farms, and income from direct sell of livestock and their byproducts and by renting them as well as food.

Regarding the Land use type and size by each land use type, it has summarized in Table 3. In the study area, land is the most important asset and livelihood source for the farm households. Farm households in the study area use land for different purposes, such as for production of different crops, for grazing land in livestock production, for village and other types of construction purposes, and for other different purposes. The land use types and the size of the land used in the study area is summarized in Table 3.

Table 3. Land use in the study area during 2014/2015 cropping season

Land use types	Total Land use in (Ha) and in (%) by study woredas			
	Ankober	Basona	Angollela	Total
Total farm land size	13138 (13.06)	63185 (62.81)	24280 (24.13)	100603
Grazing land	9010 (24.31)	26867 (72.51)	1178 (3.18)	37055
Forest land	23218 (39.29)	23485 (39.74)	12393 (20.97)	59096
Other land uses	32509 (25.38)	34544 (26.97)	61049 (47.66)	12810
Meher/Kiremit farm land	13098 (16.86)	42828 (55.12)	21780 (28.02)	77706
Belg farm land size	5971 (51.85)	2899 (25.17)	2646 (22.98)	11516
Irrigation farm land	2611 (20.47)	4984 (39.07)	5161 (40.46)	12756
Cereals farm land	15468 (26.38)	26380 (45)	16778 (28.62)	58626
Pulses farm land	5725 (20.77)	15245 (55.30)	6600 (23.94)	27570
Oil crops farm land	384 (25.43)	500 (33.11)	626 (41.46)	1510
Vegetable farm land	202 (17.47)	677 (58.56)	277 (23.96)	1156
Barley farm land	5974 (19.33)	11649 (37.69)	13282 (42.98)	30905
Wheat farm land	2331 (11.92)	10263 (52.49)	6957 (35.58)	19551
Teff farm land	1244 (98.65)	-	17 (1.35)	1261
Sorghum farm land	4502 (61.50)	2409 (32.91)	409 (5.59)	7320
Maize farm land	1871 (63.62)	904 (30.74)	166 (5.64)	2941

Source: The study *woredas* (*Ankober*, *Angollela*, and *Basona woreda*) office of agriculture 2014/2015; and numbers in parentheses represent percent

Regarding the grazing land distribution, out of the total (37055) Ha in the study area, 9010 (24.31%) in *Ankober,* 26867 (72.51%) in *Basona*, and 1178 (3.18%) in *Angollela woredda*, which shows that the larger grazing land size is found in *Basona woreda* and the least size of grazing land is found in *Angollela woreda*. The more land use types and land size distribution by each study *woreda* is summarized in the Table 3 that include Farm land, Grazing land, Forest land, *Belg* land, Irrigation land, and land for construction and other purposes.

The farm land size distribution in (Ha), by production season (Main/*Meher/Kiremit*, *Belg/*small rainy season and by irrigation farmland use) has summarized in the study *woreda* in Table 3. The farm land use for different agricultural crops, such as for cereal crops, Farm land for pulse crops, Farm land for oil crops, and Farm land for vegetables) has also indicated in the Table 3. Furthermore, the farm land distribution for cereal crops such as for barley, wheat, *teff*, sorghum, and maize crop for each study *woreda* has indicated in hectare and in percent as shown in Table 3. The total farmland size in the study area is (100603 ha). Out of which, 58626 ha (58.27%) was cultivated for cereal crop production, and out of which 30905 ha (52.72%) was cultivated for barley production. The remaining cereal farm land (47.28%) was allocated for other cereal crops production that include wheat, *teff*, sorghum and maize. This shows that more than half of the cereal farm land was allotted for barley production.

Regarding barley farm land distribution by the study *woreda*, as indicated in the Table 3, out of the total barley farm land (30905 ha), 19.33% was cultivated in *Ankober woreda*, 37.69% was cultivated in *Basona woreda* and 42.98% was cultivated in *Angollela woreda*, which shows that the larger barley farm land was cultivated in *Basona* that followed by *Angollela* and the least in *Ankober woreda*. In the study area crop production has undertaken during the main and *Belg* season and using irrigation. The total farm land cultivated during the main season (*Meher/Kiremt*) production time is (77706 ha), out of which (55.12%) was cultivated in *Basona*, (28.02%) in *Angollela woreda*, and the rest (16.86%) was cultivated in *Ankober woreda*, which shows that the larger farm land was cultivated in *Basona woreda*.

Regarding *Belg* season farm land, out of the total (11516ha) *Belg* farm land, 51.85% was cultivated in *Ankober*, 25.17% in *Basona*, and 22.98% in *Angollela woreda*; which shows that more than half of the *Belg* farm land was cultivated in *Ankober woreda*, which revealed that *Ankober woreda* is more of *Belg* season producer. Concerning the irrigation farm land distribution, out of (12756 ha) total irrigation farm land, 39.07% was cultivated in *Ankobe*r, 20.47% in *Basona*, and 40.46% in *Angollela woreda*, which shows that less irrigation farm land has been cultivated in *Ankober woreda*, as compared to the two *woredas*.

3.2. Barley production and its uses in the study areas

Barley is a cool-season crop adapted to high altitudes, according to Berhanu, et. al., (2005), it is grown in a wide range of agro-climatic regions. At altitudes of about 3000 masl or above, it may be the only crop grown that provides food, beverages and other necessities to many millions of people. It grows best on well-drained soils and can tolerate higher levels of soil salinity than other crops. Under extreme marginal drought conditions, frost and poor soil fertility, barley can be grown on highly degraded mountain slopes better than other cereals in the highland of Ethiopia (Ceccarelli et al., 1999). Furthermore, on average, barley yield varies between 10 and 13 quintals per hectare. Food barley is commonly cultivated in stressed areas where soil erosion, occasional drought or frost limits other crops to grow. In the study area, the highlands of *Semen Shewa*, barley production and barley food consumption that prepared traditionally are common, and on which the livelihoods of farm households in the study area mainly dependent on barley production and consumption.

Barley contains about 75% carbohydrate, 9% protein and 2% fat. Each gram barley provides about 3.3 calories of energy. Barley grain is rich in zinc, iron, soluble fibers. Barley has also high content of Vitamins A and E than other cereals (Tura and Gashaw, 2015). In Ethiopia, barley-based foods are prepared as main dishes (*Injera* and *Kita*), as side dishes (*Kolo),* and as ceremonial/wedding/festivals dishes *checchebsa, Genfo, Beso, chuko, Kinche* and *shorba*, and many others (Berhan, et al, 1996;Jemal, et. al., 2016). Barley is used as food and raw material for brewing home-made alcoholic drinks. Barley is a source of carbohydrates, and protein (Kerssie and Goitom, 1996).

Barley is one of the most important staple food crops in the high lands of Ethiopia. Currently, it is widely consumed as a food grain with desirable nutritional contents. Barley fibers contains beta–glucans and tocotrineols, chemical agents help to lower serum cholesterol (Lee, et. al., 2007). Among local beverages, *Tella* and *Borde* are prominent, and best made from barley grain. Barley spikes both unripe at milk or dough stage and ripe and dry are also roasted over flame and the grain is consumed as snack called *Eshete* or *Wotelo* if the spikes are unripe, or *Enkuto* if the roasted barley spikes are dry (Anderson, *et. al.*, 1991). Furthermore, a large variety of dishes, including soups, bread, and couscous are made from barley products. Preparations include both product from fully mature grains and grains harvested. Some recipes, such as *Besso* (fine flour of well-roasted barley grain moistened with water, butter or oil), *Zurbegonie* (same type of flour used for *Besso* dissolved in cold water with sugar) and *Chiko (bess*o soaked with butter and spice), which have long shelf life, can only be prepared from barley grain.

Barley in the study area, as was confirmed by focus group discussion participants of this study. The food from barley prepared in the form of *Genfo, Kinche,* and *Atmit* is the best for mothers, who gave birth. *Atmit* is also good for babies to start and exercise food eating. Barley food prepared in the form of *chechebsa* and *chicko* used as a source of energy. Most of the time, *chechebsa* and *chicko* are consumed with milk and butter. Barley also used to prepare local beverages such as (*Tela, Bukri, Keneto, Areke, etc.*). Therefore, barley is the most important and multipurpose cereal crop suitable to grow and help to sustain the community in the highland areas like in *Semen Shewa* Zone, where this study was conducted.

According to Anderson, et. al., (1991), recipes, such as *Genfo* (porridge), *Kolo* (de-hulled and roasted barley grain), *Kinche* (thick cooked) are most popular when made from barley grain, but can be prepared from other cereals also.

Barley is the preferred grain, after *teff,* for making traditional bread called *Injera*, which can be used either solely or in combination with *teff* flour or other cereal flours. Other recipes, such as *Dabbo* (bread), *Kitta* (thin, unleavened, dry bread) and *Atmi*t (gruel) can be prepared with barley or blended with other cereal flours. Barley is the early harvested crop, popularly known as hunger breaker or relief crop during food shortage in some parts of Ethiopia (Bayeh and Berhane, 2011). In the highlands of Ethiopia, where barley is produced widely, its share in the consumption of communities is high. The highland communities consumed barley in different forms of traditionally prepared foods and local beverages (Zemede, 2000).

Barley grain accounts for over 60% of food in Ethiopian highlands, where barley is the main source of calories. According to Birhanu et al. (1996 and 2005), barley is used in diversity of recipes and deep rooted in the culture of people's diets. Although the day to day survival of the highland farm households is linked to barley, efforts to improve its productivity is low (Berhan, *et al,* 1996). Besides its grain value, barley straw is an important component of animal feed, especially during the dry season, where feed shortage is prevalent. Barley straw is used as animal feed due to high altitude predisposing other crops to damage by frost to which barley is relatively tolerant (Bekele *et al.,* 1998). Hence, barley straw is also used in traditional huts and grain stores thatching and as a mud plaster, as well as for use as bedding in rural areas (Zemede, 2000). Barley straw remains an important feed source in Ethiopia highlands (Grando, *et. al*, 2005). The study conducted by Kassahun, *et. al.*, (2016), farmers ranked barely straw second, next to *teff* straw in terms of palatability and easy management in Horro Guduru, Western Ethiopia.

According to Bogale, *et. al.*, (2008), out of the existing crop residues, barley straw was preferred due to its palatability and softness as compared to pulses or other cereals straw in *Dinsho*, *Bale* (Ethiopia), where barley straw is almost the sole crop residue. Barley crop is important for farm households in many aspects such as for income and food, livestock feed, roof thatching and mud plastering for households' hut and traditional grain store. Barley in the world and in Ethiopia, specifically, in the highland areas, it is critically vital in the life of rural highland farm households

Table 4. Barley varieties produced in the study area (food barley)

Farmers'/Local food barley varieties		Improved food barley varieties		
Varieties name	Productivity/ Quit/ha	Varieties name	Productivity/quint/ha	
			farmers level	research center
Maugie and Gye Gebse	15-20	HB-42	23-33	33-35
Kessele	8-12	Ardu-1260B	18-30	36-63
Feres Gama		Desta	20	25-54
Key Gebs		HB1307	35	48
Ehilzer/ Tebele	7-15	Mzezo	25-30	42
Enat Gebs		Baso	25-30-	43
Netch Gebs/Nechita	6-12	Misrach	20-39	25-54
Sene Gebs		Tila	21-31	22-40
Ginbote		Mulu	19-26	23-35
Tikur Gebse		Setegn	18-35	20-45

Malt barley varieties	Farmers' level yield Q/Ha	Research center Yield/ Ha
Holker	20-25	24-38
Miskal-12	20-46	19-52
Beka	20-25	24-48
HB-52	14-18	24-47
HB1533	10-20	18-50
Dinsho	24	19-37
HB-120	18-20	24-53
Dimtu	15-22	25-40
Agegnhu	33	39

Source: taken from the study *woreda* office documents and field work guidelines

As indicated in Table 4, there are different local and improved barley varieties grown in the study area. The farmers' varieties include (*Maugie, Gye Gebse, Kessele, Feres Gama, Key Gebs, Ehilzer/Tebele, Enat Gebs, Netch Gebs/Nechita, Sene Gebs, Ginbote*, and *Tikur Gebse*); and the improved varieties that are promoted by Research centers and office of agriculture (extension office) include (HB-42, Ardu-1260B, Desta, HB1307, *Mzezo, Baso, Misrach, Tila, Mulu, Setegn, Dimtu, AgegnhuHolker*).

3.3. Description of research methods

Qualitative and quantitative research methods were used in sample selection and data collection, in data analyses, interpretation and in result discussions. The integration and blending of quantitative and qualitative research methods are maintained in the process of this study; it is because integrating the two approaches help to examine and understand the research problem from different perspectives and to enhance the research outputs. According to, Venkatesh, *et. al.,* (2013); Reinard, (1994); and Sarantakos, (1998), using quantitative and qualitative methods in the same research inquiry help to develop rich insights into various phenomena that cannot be fully understood using only quantitative or qualitative research method. Therefore, mixed method can be employed in all stages of research activities such as in data collection, in analysis, and interpretation by mixing/integrating both quantitative and qualitative data in a single study or in a multiphase inquiry.

Furthermore, mixed methods studies combine qualitative and quantitative approaches into a single study (Tashakkori and Teddlie, 1998). Quantitative research involves the collection and analysis of numerical data, while qualitative research considers narrative (experiential) data (Hayes et al., 2013). Mixed research method, integrates qualitative and quantitative data in a single study. It is the 'mixing' of qualitative and quantitative components of the study. Furthermore, qualitative and quantitative elements are interlinked to produce a fuller account of the research problem. This integration can occur at any stage(s) in the whole research process (Zhang and Creswell, 2013).

In mixed research method, researchers combine elements of qualitative and quantitative research approaches in use of both methods, data collection, analysis, inferential techniques for broad purposes of understanding (Burke, *et. al,* 2007). According to, Greene, *et. al.* (1989), the distinctive justifications for integration of quantitative and qualitative research includes (triangulation for convergence and corroboration of results) derived from different research methods; complementarity that seeks elaboration; enhancement; illustration; clarification of results from one method with the results from another. Hence, in this study, mixed research methods that include (quantitative and qualitative methods) were employed from sampling, data collection, analysis, interpretation, conclusion and recommendation.

3.3.1. Sampling procedures

The sampling procedures used in this study to select the study areas, respondents (for quantitative data), and focus group discussion participants (for qualitative data), were both probability and non-probability). In selection of *Semen Shewa Zone* (Amhara region), three study *woredas (Ankober, Angollela* and *Basona),* and 36 focus group discussion participants (12 from each study *woreda*) were used purposive (non-probability) sampling method. To select the study *kebeles* from each study *woreda* and to select survey respondents from each selected *kebeles* random sampling methods (probability sampling) were employed. The sampling process of selection of the study areas and respondents was followed multi-stage sampling approach (Bamett, 1974). In the first stage, *Semen Shewa* Zone from *Amhara* Region was selected that followed by the selection of the study *woredas* (*Ankober, Angollela* and *Basona woreda*). In the third and fourth stages, the study *kebeles* and respondents for survey data and qualitative data were selected respectively as indicated in Table 5.

To determine the size of the male and female sample HHs, proportional to size approach was employed. The study areas selection, from the Zone to the study *woredas*, the proximity and road accessibility in relation to the research budget were considered in to account. In determining the number of *Kebeles* and respondents also the research budget and time for analysis were considered in addition to the research budget availability.

Table 5. Sampling processes

Stages in sampling process						
First	Second	Third	Fourth stage (respondents' selection for survey data)			FGD participants selection
Zone selection	*woreda* selection	*Kebele* selection	Survey respondents selection			
			Male	Female	Total	
Semen Shewa Zone/Amhara	*Ankober*	Ligoregela	70 (77.78)	20 (22.22)	90 (33.33)	12
		Chefana	66 (75.86)	21(24.14)	87 (32.22)	
		Derefo	72 (77.42)	21 (22.58)	93 (34.44)	
		Total	**208 (77)**	**62 (23)**	**270 (100)**	
	Basona	Debele	58 (71.60)	23 (28.40)	81(29.78)	12
		Dibut	67 (69.07)	30 (30.93)	97 (35.66)	
		Gudoberet	66 (70.21)	28 (29.80)	94 (34.56)	
		Total	**191 (70.22)**	**81 (29.78)**	**272 (100)**	
	Angollela	Tsigereda	90 (78.26)	25 (21.74)	115 (42.59)	12
		Bura	48 (71.64)	19 (28.36)	67 (24.81)	
		Asaberet	67 (76.14)	21 (23.86)	88 (32.60)	
		Total	**205 (75.93)**	**65 (24.07)**	**270 (100)**	
Total	**3 *woredas***	**9 *Kebeles***	**604 (74.38%)**	**280 (25.62%)**	**812 (100%)**	36

Source: own organization; and Number in parenthesis represents percent

In the selection of sample *kebeles*, first, the total rural *kebeles* in each study *woreda* were classified in to potential and less potential barley producing *kebele*s with the consultation of DAs, and *Kebele* leaders. Then, the less potential *kebeles* were left out from sampling. Only, the barley potential rural *kebeles* were selected randomly. From each selected *woreda*,, a total of nine barley-potential *kebeles* were selected, and from which 812 sample households (604 males and 208 female) were selected and cross sectional survey were employed to collect quantitative data and for qualitative data, three focus group discussions (FGDs), one FGD with 12 participants in one study *woreda*, a total of 36 focus group discussion participants in three FDGs were participated.

3.3.2. Data types, sources and collection methods

Data collection was carried out in December 2014 and January 2015. The data types were quantitative and qualitative; and the data sources were including primary and secondary sources, which means, the primary and secondary data were collected from primary and secondary sources. The primary sources were the survey respondents and focus group discussions (FGDs); and the secondary data sources were collected from offices of agriculture in Semen Shewa Zone and study *woredas (Ankober, Basona* and *Angollela*) and from DAs' offices and *kebele* administration offices of the study areas. More further, the secondary data were collected from journal articles and CSA Website.

The data that was collected from primary sources were using quantitative and qualitative data collection methods that include survey questionnaire and checklist; while data from secondary sources were collected through record reviewing of the respective offices. Trained enumerators were used to collect data from respondents using pretested questionnaire. Enumerators were also supervised by the trained supervisors and researcher to maintained the quality of the data. In survey data collection, 9 supervisors and 27 enumerators were participated, after they got adequate training. Data were collected from 812 respondents (male 604 and female 208), and from 36 focus group discussion participants. Qualitative data from focus group discussion was collected using checklist that was comprised the discussion points to be discussed by the focus group discussion participants. The focus group discussion participants' opinions were recorded by the researcher and by the assistants trained to assist the researcher in recording and note taking of the opinions of FDG participants.

3.3.3. Data analysis methods

Data analyses were conducted using quantitative and qualitative methods. In quantitative methods, descriptive statistics, econometric models (binary and ordered logit, censored Tobit, multivariate probit and multi-linear regression models were employed; while in qualitative data analysis, narration, explanation, contextualization and triangulation of the opinions of focus group discussion participants were conducted.

In this study, before the beginning of data analyses, data were cleaned, edited, organized, arranged, coded and entered in SPSS-version 22 and STATA-version 13 computer software programs and make ready for further analyses. Then, the next step, analyses of the data for each of the objective using quantitative and qualitative methods were undertaken. Furthermore, before running the models pretests to check the existence of multicollinearity problem, both for continuous and non-continuous explanatory variables were conducted using variable inflation factor (VIF) for continuous predictors and using correlation matrix for non-continuous predictors. Finally, the model for each of the objectives was run; and the results were interpreted and compared with the previous research findings. Qualitative data were processed and refined as well as interpreted.

Table 6. The dependent and independent variables summary those used in econometrics models analyses of this study

Econometrics model	Econometrics model	Variables and their coefs. expected signs	
Types	Application/uses	Dependent	Independent
Multivariate probit model	barley technologies adoption determinants	7 adopted barley technologies	13 (6cont.+7non-cont.)
Censored Tobit model	fertilizer adoption Intensity (kg)	Fertilizer adopted in Kg	21 (8cont,13 non-cont)
	barley income intensity (Eth. Birr)	Income from barley (E.Birr)	22 (7cont,15non-cont)
	barley food availability intensity (Kcal)	Food availability from barley (Kcal)	20 (6count,14non-cont)
Multi-linear regression model	Aggregate income intensity (Eth. Birr)	Total HHs' income (Eth. Birr)	20 (6cont. & 14 non-cont.)
	Aggregate food availability intensity (kcal)	Total HHs' food availability (Kcal)	20 (6cont,14non-cont)
Binary logit model	Aggregate income status determinants	income equal/above or below 3781 Eth. Birr	20 (7cont. &13 non-cont.)
	Aggregate food availability status determinants	food availability equal and >; or < 2550 (Kcal)	16 (6cont. &10non-cont)
Ordered Logit	HHs' perception level determinants	3 perception levels (low, medium, high)	14 (7cont.&7non-cont.)
Censored Tobit	Intensity of mean perception determinants	HHs' intensity of mean perception	13 (8cont.&5non-cont.)

Source: own organization from own data

In the interpretation of the qualitative data, it was used to complement with the quantitative analyses results, if not, stand by independently. However, there was no divergence data between quantitative and qualitative data analyses and interpretations. Furthermore, the VIF and correlation matrix results are presented in each section of the econometrics model analysis. In Table 6, the dependent and independent variables and the regression models employed in this study are summarized to easily comprehend what models and variables for each objective were employed.

3.3.4. Selection and description of dependent and independent variables and models specification

The selection and description of dependent and independent variables, and the econometrics model specification were conducted. The dependent and independent variables to which descriptions were given and econometric models for those study, in which the dependent and independent variables were entered for analysis, and the objectives analyzed using the variables and econometric models were summarized and indicated in the Table 9 to easily understand the components and processes the analytical econometrics analysis of data in this study; and in the following section, the dependent and independent variables description and the models specifications are given.

3.3.4.1. Dependent and independent variables and analytical model specification in barley technologies adoption

Dependent variables description:

Dependent variable is a variable affected or explained by another variable/s, which are independent variable/s. In this study, the dependent variables are more than one, which are seven that include (fertilizer adoption, compost adoption, weedicide adoption, barley farm land frequent plow-3 and above, frequent hand weeding of barley-2 or more times weeding, adoption of improved barley seed varieties, and barley farm land drainage practice). Each of the variable took the dichotomous value depending on the farm household's decision either to adopt or not. As a result, when the farm household adopt the technology, the household is called adopter, represented by the value 1; otherwise, non-adopter, represented by Zero (0). Therefore, adopters are farm households, who utilized one or more of the mentioned improved technologies and practices necessary for barley production; while non-adopters are farm households who did not use either of the mentioned barley technologies and practices during the survey year, 2014/2015.

Description of independent variables used in barley technologies adoption

The independent variables hypothesized in this study are those expected to influence the dependent variable, adoption of improved barley technologies, which has 7 categories that include (adoption of fertilizer, compost, weedicide, barley farm land frequent plow three and more times, frequent hand weeding of barley/two and more times, improved barley seed varieties, and barley farm land drainage practice). The independent variables hypothesized to affect the dependent variable, barley technologies adoption were 13 as indicated in the Table 7,which also grouped in to continuous and non-continuous as well as in to personal and demographic variables, economic and resource ownership, institutional factors, etc.

Table 7. List of independent variables used in barley technologies adoption

Explanatory variables hypothesized to affect barley technologies adoption	Continuous/Non-continuous	Expected Coef. sign
Household head age in (yrs)	Continuous	-
Household's Livestock size (TLU)	Continuous	+
Household's farm land size (Ha)	Continuous	+
Household size in Adult Equivalent	Continuous	-
Household's home distance from market (Km)	Continuous	-
HH head formal education in (yrs) of schooling	Continuous	+
Household head sex	Non-continuous	-
Household's income status	Non-continuous	+
Household's credit access	Non-continuous	+
HH's access to agricultural extension service	Non-continuous	+
Household's food availability status	Non-continuous	+
HH's participation in barley output markets	Non-continuous	+
HH's participation in land rent-in practice	Non-continuous	+

Source: own organization

According to Feder and Zilberman (1985), household's specific variables including age, farm experience; gender and income are important factors influencing farmers' decision to adopt new technology. The independent variables used in this study are listed with their brief characteristics as indicated Table 7. For further information, the detail description has been given in Annex 1.1.

Econometrics model specification (Multivariate probit model)

Multivariate probit model was selected and used to analyze barley technologies adoption determinants. In this study, barley technologies (fertilizer, compost, improved barley seed, weedicide, pesticide, improved agricultural practices such as frequent hand weeding/two or more times and oxen plowing/three or more times) were used as dependent variables; while independent variables include different socio-economic and demographic factors, locations and access of farm households to different services, physical assets, infrastructures, etc. When the dependent variables are more than two; and when farm households adopt more than one of the dependent variable (technology), multivariate probit model is recommended. In multivariate probit model, each dependent variable took the dichotomous value that when farm households use or adopt the improved technology (dependent variable), the farmer is called adopter, represented by one (1); otherwise, non-adopter represented by Zero (0). Multivariate probit model gives a chance to estimate, when the farm households adopt more than one technology. The specification of multivariate probit model is given here in below:

The multivariate probit model, for observation "i" and equation "j", is specified as:

$$Y_{ij}^* = X_i\beta_j + u_{ij} \quad \ldots\ldots\ldots\ldots (1)$$

$$Y_{ij} = 1(Y_{ij}^* > 0) \ldots\ldots\ldots\ldots (2)$$

$$U_i = [, \ldots, U_{iM}] \sim MVN(O, R) \text{ or } Y_i^* = [Y_{i1}, , Y_{iM}] \sim MVN(X_i B, R) \ldots\ldots\ldots (3)$$

Where i=1,... ,N indexes observations, j=1,... ,M indexes outcomes, X_i is a K---vector of exogenous covariates, the U_i is assumed to be independent across i, but correlated across j for any i, and "MVN" denotes the multivariate normal distribution. (Henceforth the "i" subscripts will be suppressed). The standard normalization sets the diagonal elements of R equal to 1so that R is a correlation matrix with off---diagonal elements ρ_{pq} , $\{pq\} \epsilon = \{1, \ldots, M\}$, p≠q·[2]With standard full rank conditions on the X's and each $|\rho_{pq}| < 1$, then B = $[\beta_{1,\ldots\ldots,}\beta_M]$ and R will be identified and estimable with sufficient sample variation in the x's.

3.3.4.2. Variables description and model specification in fertilizer adoption

Description of Dependent Variable

The dependent variable used in this analysis of chemical fertilizer adoption took the continuous value measured the quantity of fertilizer in (kg) used by the adopter farm households during the survey year, 2014/2015. However, for further information, the detail description of each predictor has given and presented in Annex 1.2 section of this study.

Description of Independent Variable

In this study, the independent variables that were selected and hypothesized to affect the farm households' adoption of chemical fertilizer measured in (Kg) in their barley production.

Table 8. List of independent variables used in fertilizer adoption (Kg)

Independent variables hypothesized to affect farm HHs' adoption of chemical fertilizer	Continuous/non-continuous	Expected Coef. sign
HH head age in (years)	Continuous	-
HH head formal education (years)	Continuous	+
HH size in adult equivalent	Continuous	-
HHs dependency ratio	Continuous	-
Livestock Size (TLU)	Continuous	+
Farm land size (Ha)	Continuous	+
Market distance (Km)	Continuous	-
HHs' home distance from FTC in Km	Continuous	-
HHs' home distance from DA office in Km	Continuous	-
Credit center distance Km	Continuous	-
All weather distance Km	Continuous	-
HHs' ownership in number	Continuous	+
Household sex	Non-Continuous	+
Household food avail. Status	Non-Continuous	+
Household income status	Non-Continuous	+
Farm households credit access	Non-Continuous	+
Farm HHs' access to Extension service	Non-Continuous	+
Farm HHs' participation in barley selling options	Non-Continuous	+
HHs' participation in land-rent-in practice	Non-Continuous	+
HHs' marital status	Non-Continuous	+
HHs' participation in livestock shared-in	Non-Continuous	+
HHs' participation in *Belg* crop production	Non-Continuous	+
HHs' participation in irrigation production	Non-Continuous	+
HHs' participation in rain fed crops support with irrigation	Non-Continuous	+
HHs' participation in improved livestock production	Non-Continuous	+

Source: own organization

The Independent variables proposed in this analysis were used in this analysis were 25 grouped in to 12 continuous and 13 non-continuous predictors as indicated in the Table 8.

Econometrics regression model specification (Censored Tobit Regression Model) used in fertilizer adoption

Limited dependent variables models have been used in technology adoption studies. In adopting new technologies, decision makers (farmers) are assumed to maximize utility (profit) from using new technologies subject to some constraints (Feder, *et al*, 1985). In categorical dependent variables (binomial/multinomial) qualitative choice models of adoption (logit/Probit) model are specified, which are commonly used to analyze situations where the choice problem is whether or not (0-1 value range) to adopt a new technology. However, intensity of use of improved technologies is a very important aspect of technology adoption because it is not only the choice to use but also how much to apply is more important.

The Tobit model of Tobin (1958) is used to handle the distribution of dependent choice variables such as level/quantity of fertilizer use, where the same approach is used in this study. The model is appropriate in explaining relationships involving a continuous dependent variable and a set of independent variables; and studying decisions where error terms are truncated or censored (Bamire, *et al.,* 2002). The advantage of Tobit model over the dichotomous choice models, such as, Probit model (Finney, 1971) and Logit model (Aldrich and Nelson, 1984) is that it permits determining the intensity of use of technology once adoption has taken place. In this study, Tobit model specification to analyze determinants affecting the intensity of fertilizer use/adoption during the survey year is presented here as indicated here in below:

$FADI = \times\, \beta(z) + f(z) + \varepsilon$

$FADI^{*}, if FADI^{*} > FADI_0$

$0, if \;\; FADI^{*} < FADI_0,$ Where, FADI (Fertilizer Adoption Intensity) is the adoption intensity (fertilizer quantity), 0, FADI is the critical value adoption intensity, ε is the standard error term, f (x) is the value of the derivative normal curve at a given point (density function), $\times$ is the vector of explanatory variables, z, is the Z-score, β is the vector of parameters. McDonald and Moffit (1980) showed that the marginal effect of explanatory variable on the expected value of the censored (truncated distribution) dependent variable is given by,

$$\frac{\partial E(FADI)}{\partial x_i} = F(z)\beta_i$$

On the other hand, the change in the probability of adoption as the explanatory variable xi changes is given by:

$$\frac{\partial F(z)}{\partial x_i} = \frac{f(z)\beta_i}{\sigma}$$

And the change in the intensity of adoption among adopters as an explanatory variable change is given by:

$$\frac{\partial (FADI^{*})}{\partial x_i} = \beta_i \left[1 - \frac{zf(Z)}{F(Z)} - \frac{f(Z)^2}{F(Z)^2}\right]$$

3.3.4.3. Variables description and model specification in farm HHs' perception level

Description of the dependent variable: Perception is a process of receiving information and stimuli from our surroundings and converting them into psychological responsiveness (Van den Ban and Hawkins, 2000). Perception, according to Maddox, (1995) refers to the process of acquisition and understanding of information from one's environment. In this study, data on farm households' perception was collected using the five likert scale. However, in regression analysis using ordered logit econometrics model, the five scales reduced/condensed in to three levels for simplicity of analysis and interpretation of the result. Farm households' perception level towards agricultural extension service has grouped in to three categories that include low, medium and high perception of the households towards agricultural extension service, which are represented by (1); (2); and (3) respectively.

Description of independent variables: The independent variables selected to use in the analysis of farm households' perception level towards agricultural extension service were fourteen (14), which all were included in the ordered logit regression model for further analysis after checking for the multicollinearity problems. Out of total 14 predictors, 7 were continuous; and the other 7 were non-continuous as indicated in the Table 9. For further information, the detail description of independent variables has been given in Annex 1.3.

Table 9. List of independent variables used in the analysis of farmer' perception level

Independent variables affecting the dependent variables	Continuous/Non-continuous	Expected coef. sign
Household's head age in years	Continuous	-
HH head formal education in (years) of formal schooling	Continuous	+
Household size in adult equivalent	Continuous	+
Household's Livestock size (TLU)	Continuous	+
Household's farm land size (Ha)	Continuous	+
Credit center distance (Km)	Continuous	+
Market distance (Km)	Continuous	+
Household's head sex	Non-continuous	+
Households' food availability status	Non-continuous	+
HH's participation in improved Livestock Production	Non-continuous	+
Households' income status	Non-continuous	+
Farmers' training center availability	Non-continuous	+
barley technologies adoption in number	Non-continuous	+
Frequency of Extension contacts	Non-continuous	+

Source: Own organization

Econometrics regression model specification (Ordered Logit Regression Model) in households' perception level analysis

In the analysis of determinants hypothesized to affect barley farm households' perceptions towards agricultural extension service, ordered Logit regression model was employed. The data was collected from respondents using the five scale Likert scale questionnaire. In the questionnaire, 9 separate Likert statements/items/questions were prepared to be answered by respondents) After data collection for analyze of determinants affecting farm households' perception, the five Likert scale data was analyze separately. In the analysis, the respondents' response for the nine items were summed up and divided for the nine questions /items to get individual respondent's mean perception towards agricultural extension service. As a result, sample farm households were categorized/sub-grouped in to three groups that sample farm households with (Low, medium and high perception) towards agricultural extension service. As a result, those whose mean value is below 3 were considered as households with low perception represented by 1. Those, whose mean value equal to 3 were considered as households with medium perception, represented by 2 and those whose mean perception is above 3 were considered as households with high perception represented by 3.

Ordered logit model, as discussed by Long (1997) was developed independently in social sciences (in underlying latent variable with observed, ordered categories). According to Chen and Hughes, (2004a), in inferential statistics analysis to determine the relationships between multiple independent and dependent variables, and to determine significant predictors related to dependent variable, commonly, regression models are used. The regression models can also be used to describe the magnitude and direction of predictors' effects on the dependent variable. When the response variable of interest is ordinal, ordered logit regression model can be used (Grilli and Rampichini, 2014). Often, dependent variables are ordinal, but are not continuous, in the sense that the metric used to code variables is meaningful (Jackman, 2000).

According to Min (2013), the ordinal dependent variable is non-linear, represented by 0 to 1 probability as in a Logit model; a non-linear model must have a different error structure and the error term does not have constant variance. The use of Logit model can be easily denied, because the Logit model cannot deal with a dependent variable with more than two categorical and ordered outcomes in an appropriate way. According to Leitner (2003); and Long and Freese, (2003), if the aforementioned ordinal dependent variables are developed as dichotomous variables, the Logit model is employed to estimate the logit coefficients; but the results lead to loss of important information about dependent variables. Hence, ordered Logit or probit model is considered most appropriate since the dependent variable is ordinal. As mentioned in the above, to measure the respondents' perceptions, which represent the dependent variable having the ordinal nature (low, medium and high perception), the best-fitting statistical model for handling the ordered outcome is known as an ordered-logistic regression model, which will be used as an analytical model in this study to determine factors expected to affect the farm households' perception towards agricultural extension service).

The explanation of the ordered logit regression model is given here below. According to Long and Freese (2003), symbols rather than actual variable names are used. Then, Y is an ordinal dependent variable with c categories, and Pr (Y ≤ j) denotes the probability that the response on Y falls in category j or below (i.e., in category 1, 2…or j). This is called a cumulative probability. It equals the sum of the probabilities in category j as shown below;

Pr(Y ≤ j) = Pr(Y =1) + (Pr(Y = 2) +Pr(Y = j) ………………………………..……….. (1)

A "c-category Y-dependent variable" has c cumulative probabilities: Pr(Y ≤1), Pr(Y ≤ 2); Pr(Y ≤ c). The final cumulative probability uses the entire scale; as a consequence, therefore, Pr($Y \leq c$) = 1. The order of forming the final cumulative probabilities reflects the ordering of dependent variable scale, and those probabilities themselves satisfy:

Pr($Y \leq 1$) ≤ Pr($Y \leq 2$) ≤ ....(1)

≤ Pr($Y \leq c$) = …………………………………………………………...………. (2)

In ordered logit model, an underlying probability score for an observation of being in the ith response category is estimated as a linear function of the independent variables and a set of cut points. The probability of observing response category i corresponds to the probability that the estimated linear function, plus random error, is within the range of the cut points estimated for that response (Min, 2013).

Pr (Response Category for the jth outcome, Pr ($k_{k-1} < b_1 x_{1j} + b_2 x_{2j}$ +…$b_k x_k + u_j \leq k_i$)..(3). It is necessary to estimate the coefficients of $b_1, b_2 \dots, b_k$ along with cut points $k_1, k_2, \dots, k_{i-1}$,

where "i" is the number of possible response categories of the dependent variable. The coefficients and cut points are estimated using maximum likelihood. As a result, the dependent variable towards households' perception towards agricultural extension has three ordered categories (low, medium and high), and each category of the dependent variable has been affected by the independent variables mentioned in the above. Therefore, ordered Logit regression model has been chosen and used to identify determinants that are hypothesized to affect farm households' perception towards agricultural extension service in the study area.

3.3.4.4. Dependent and independent variables description and model specification in farm HHs' intensity of perception towards agricultural extension service

Description of dependent variable

The dependent variable, used in this study is the farm households' intensity of perception measured as continuous variable by calculating the respondent's mean perception from the sum of responses of each respondent obtained from nine statements (organized in five Likert scales/options); and by dividing the sum to nine (the number of items/statements). Then, the result represents the mean perception (intensity of perception) of each respondent towards agricultural extension service. The mean perception of each respondent was entered in ordered Logit regression model for further analysis to identify those factors influencing the intensity of farm households' perception towards agricultural extension service offered to the farm households in the study area. Regarding the concept of perception, it can be defined, according to Blaikie, *et al.,* (1ultural, 997), as the beliefs or opinions often held by many people based on how things seem to them; while knowledge, on the other hand, concerns the way people understand the world, and how they interpret and apply meaning to their experiences. Both perception and knowledge guide decision making and consequently, farmers' action (Kisauzi, *et. al.,* 2012).

Description of Independent Variables

the independent variables, selected to be used in this study to analyze the farm households intensity of perception towards agricultural extension service offered in the study area. The independent variables selected to be used in this study were 13, which were grouped in to two that include 8 continuous and 5 non-continuous as indicated in the Table 10. However, for further information, the detail description has been given in the Annex 1.4.

Table 10. List of independent variables used in farmers' intensity of perception analysis

Independent variables used to analyze farm households' intensity of perception towards extension service	Continuous/ non-continuous	Expected coef.sign
Household age (years)	Continuous	-
HHs head formal education (years of schooling)	Continuous	+
Household's Livestock size (TLU)	Continuous	+
Household's farm land size (Ha)	Continuous	+
Credit center distance (Km)	Continuous	-
Market distance (Km)	Continuous	-
Household's income in Eth. Birr	Continuous	+
DA office distance (Km)	Continuous	-
Household's head sex	Non-continuous	+
Households access to agricultural extension service	Non-continuous	+
HH's participation in improved livestock production	Non-continuous	+
Household's off-farm participation	Non-continuous	+
HH's participation in barley value addition practices	Non-continuous	+

Source: Own organization

Econometrics Regression Model Specification (Censored Tobit Model) used in farm households' intensity of perception

Regression Model used in the determination of farm households' intensity of perception towards agricultural extension service was censored Tobit regression model; which used to establish the relationship between the extent of farm households' mean perception towards agricultural extension service as regard to barley technologies adoption, and the explanatory variables selected and hypothesized to affect the dependent variable of this specific objective, intensity of perception. The decision of a farm household to use chemical fertilizer is complex and consisting of two processes. The first involves making the decision to adopt the technology as production technology in the first place, while the second involves deciding on the level i.e. the intensity or extent of use of that technology, given that adoption has taken place (Sall et al., 2002; Shiyani et al., 2002; Wabbi et al., 2006). In its simplest form, the Tobit model is presented here in below:

In its simplest form, the Tobit model is presented as:

$\mu_i^* = \beta_{xi} + \mu$

Algebraically expressed for the i_{th} farmer;

$\mu_i = \beta_0 + \beta_1 \times_1 + \ldots\ldots\ldots\ldots \beta_n \times_n \; i = 1 \ldots\ldots . . N \ldots\ldots\ldots 0 \; if \; \mu^* \leq T$

$\mu i = \mu_i^* \; if \; 0 < \mu^* < 1$ (i=1…………………………………………...…. n)

$1 \; if \; \mu_i^* > T$

Where, μ_i = the observed dependent variable i.e. the farm households' mean perception towards agricultural extension service;

$\mu_i^* =$ the non-observable latent variable representing the farm households' mean perception towards agricultural extension service;

T= the critical (cut off) value which translates into$\mu_i^* > T$as a farm household perceives, and $\mu_i^* < T$ as a farm household' perception is below or above the critical value; and

n = the number of observations.

The censored Tobit regression model is appropriate in explaining relationships involving a continuous dependent variable and a set of independent variables (Akinola, 1987; Bamire et al., 2002; Sall et al., 2002 studying where error terms are truncated or censored (McDonald and Moffit, 1980). The advantage of censored Tobit model over the dichotomous choice models such as the Probit model (Finney, 1971) and the Logit model (Aldrich and Nelson, 1984) is that it permits determining the intensity of the dependent variable, like in this case is the farm household's perception towards agricultural extension service.

3.3.4.5. Farm households' barley income determinants and models specification

Dependent variables description

The dependent variable used in this analysis was farm households' income intensity from barley is the continuous variable measured in (Eth. Birr), which was expected to be affected by different factors that include demographic, socio-economic, environmental and other different resources. Their effects on the dependent variable were estimated using censored Tobit regression model using stata-version-13 software. The selected explanatory variables list has presented in Table 11, and their detail description also given in the Annex 1.5.

Independent variables description

As shown in Table 11, seven continuous and fifteen non-continuous predictors that were used in the analysis of barley income determinants.

Table 11. List of predictors used in the analysis of farmers' barley income (Eth. Birr)

Independent variables used in the analysis of farm households' income from barley	Continuous/Non-continuous	Expected sign of coef
Household head age	Continuous	-
Household head formal education in years of schooling	Continuous	+
Household's size in Adult Equivalent	Continuous	-
Household's Livestock size in (TLU)	Continuous	+
Household's farm land size (Ha):	Continuous	+
Household's home distance from market (Km)	Continuous	-
Household aggregate food availability(Kcal)	Continuous	+
Household's head sex	Non-continuous	+
Households' fertilizer adoption	Non-continuous	+
Household's adoption of compost	Non-continuous	+
Household's weedicide adoption	Non-continuous	+
Household's adoption of frequent plow	Non-continuous	+
Household's adoption of frequent weeding	Non-continuous	+
Household's adoption of improved seed	Non-continuous	+
Household's adoption of farm drainage	Non-continuous	+
Household's access to formal credit	Non-continuous	+
Farm household's off-farm participation	Non-continuous	+
Household's access to barley extension service	Non-continuous	+
Farm household's participation in Land Rent-in practice	Non-continuous	+
Farm HH's participation in barley value additions	Non-continuous	+
Farm HH's income participation in irrigation production	Non-continuous	+
Farm households' participation in *Belg* production	Non-continuous	+

Source: Own organization

The explanatory/independent variables hypothesized to affect the dependent variable, income from barley measured in (Eth. Birr). Among which, seven (7) explanatory variables were continuous and the rest (15) were non-continuous as indicated in Table 11. Selection and description of explanatory variables; coding and entering in the model, as well as, testing for multicollinearity problem, before running the model to estimate the effect of independent variables on the dependent variable. In this analysis, censored Tobit regression model and Stata version-13 software program were employed. Following model running, interpretation of the model output (significance of explanatory variables) were conducted. The list of explanatory variables hypothesized in this analysis are indicated in Table 11. However, for further information, their detail descriptions have given in the Annex 1.5.

Econometrics regression model specification (Censored Tobit Regression Model) used in the analysis of farm household income from barley

The econometrics model, censored Tobit regression model was selected and employed to analyze factors affecting farm household's income intensity from barley. This model was chosen because, it has an advantage over other adoption models (LPM, Logistic, and Probit) in that, it reveals both the probability and intensity of use. Following Amemiya (1985), Maddala (1992) and Johnston and Dinardo (1997), the Tobit model can be defined as:

Yi* =bXi+ *i u* i = 1, 2………………………………………………………………….…… n

Yi = Yi* if Yi* > 0 ……………………………………………………………………… (1)

= 0 if * £ 0 *i Y*

Where,

Yi = the observed dependent variable, in our case proportion of area allocated to ISM

Yi* = the latent variable which is not observable

Xi = vector of factors affecting adoption and intensity of technology use

βi = vector of unknown parameters

μi = residuals that are independently and normally distributed with mean zero and a common variance σ^2.

Note that the threshold value in the above model is zero. This is not a very restrictive assumption, because the threshold value can set to zero or assumed to any known or unknown value (Amemiya, 1985). The Tobit model shown above called as censored model because it is possible to view the problem as one where observations of Y* at or below zero are censored (Johnston and Dinardo, 1997). The model parameters are estimated by maximizing the Tobit likelihood function of the following form (Amemiya, 1985 and Maddala, 1997).

$$L = \prod_{yi^*>0} \frac{1}{\sigma} f\left(\frac{Y_i - \beta_i X_i}{\sigma}\right) \prod_{Yi^* \leq 0} F\left(\frac{-\beta_i X_i}{\sigma}\right) \qquad (2)$$

Where f and F are respectively, the density function and cumulative distribution function of Y_i^*. $\prod_{Y_i^* \leq 0}$ means the product over those i for which $Y_i^* \leq 0$, and $\prod_{Y_i^* > 0}$ means the product over those i for which $Y_i^* > 0$.

It may not be sensible to interpret the coefficients of a Tobit in the same way as one interprets coefficients in an uncensored linear model (Johnston and Dinardo, 1997). Hence, one has to compute the derivatives of the estimated Tobit model to predict the effects of changes in the variables. According to Johnston and Dinardo (1997); Nkonya et al. (1997), McDonald and

Moffit (1980) proposed the following techniques to decompose the effects of explanatory variables into intensity of income from barley in this particular study, where there are farm households who have not income from barley. Thus, a change in Xi (explanatory variables) has two effects. It affects the conditional mean of Yi* in the positive part of the distribution, and it affects the probability that the observation will fall in that part of the distribution. Similar approach is used in this study.

1. The marginal effect of explanatory variable on the expected value of the dependent variable is:

$$\frac{\partial E(Y_i)}{\partial X_i} = F(z)\beta i \quad (3)$$

Where, $\frac{\beta_i X_i}{\sigma}$ is denoted by z, following Maddala, (1997)

2. Change in barley income intensity probability as independent variable Xi changes is:

$$\frac{\partial F(Z)}{\partial X_i} = f(z)\frac{\beta_i}{\sigma} \quad (4)$$

3. change in intensity of income from barley where there is change in explanatory variable is:

$$\frac{\partial E(Y_i / Y_i^* > 0)}{\partial X_i} = \beta_i\left[1 - Z\frac{f(z)}{F(z)} - \left(\frac{f(z)}{F(z)}\right)^2\right] \quad (5)$$

Where, F(z) is the cumulative normal distribution of Z, f(z) is the value of derivative of normal curve at a given point (i.e., unit normal density), Z is the z-score for the area under normal curve, β is a vector of Tobit maximum likelihood estimates and σ is the standard error of the error term.

3.3.4.6. Dependent and independent variables description and model specification in farm HHs' aggregate income intensity determinants

Dependent variable description:

The dependent variable (farm households' aggregate income intensity) is the continuous variable measured in (Eth. Birr). The households' minimum required income, per day, per adult equivalent person, according to CSA and WFP (2014), is (3781 Eth. Birr). In this study, the available intensity of farm households' income was calculated tom assess the available income intensity for the farm households; and their income intensity determinants were identified using stata-version-13. Determinants affecting households' income intensity were selected, described, entered in the model and tested for multicollinearity problems before running the model for the final output that gives the effects of the explanatory variable on the dependent variable households' income intensity. Following model running, interpretation of model output was conducted. The list and brief description of explanatory variables used in this analysis has given in Table 12, and their detail description for further information has presented in Annex 1.6.

Independent variable description:

The independent variables hypothesized to be used in this analysis were 20 (7 continuous and 13 non-continuous explanatory variables) as indicated in the Table 12. However, the detail description of explanatory variables used in this analysis (households' aggregate income intensity) has given in the Annex 1.6.

Table 12. List of independent variables used in the analysis of farmers' aggregate income intensity (Eth. Birr)

Independent variables used to analyze farm HHs' aggregate income intensity (Eth. Birr)	Continuous/non-continuous	Expected coef. sign
Household head age	Continuous	-
Household head formal education in years of schooling	Continuous	+
Household's size in Adult Equivalent	Continuous	-
Household's Livestock size in (TLU)	Continuous	+
Household's farm land size (Ha)	Continuous	+
Household's home distance from market (Km)	Continuous	-
Household's head sex	Non-continuous	+
Households' fertilizer adoption	Non-continuous	+
Household's adoption of compost	Non-continuous	+
Household's weedicide adoption	Non-continuous	+
Household's adoption of frequent plow	Non-continuous	+
Household's adoption of frequent weeding	Non-continuous	+
Household's adoption of improved seed	Non-continuous	+
Household's adoption of farm drainage	Non-continuous	+
Household's access to formal credit	Non-continuous	+
Household's off-farm participation	Non-continuous	+
HH's participation in barley output market options	Non-continuous	+
Household's access to barley extension service	Non-continuous	+
HH's participation in improved livestock production	Non-continuous	+
Farm HH's participation in Land Rent-in practice	Non-continuous	+

Source: own organization

Econometrics regression model specification (Multi-linear Regression Model) used to analyze farm households aggregate income intensity

Analytical Regression Models specification (Multi-linear Regression Model/Multiple Linear Regression Model) to use in the analysis of determinants affecting farm households' income intensity measured in (Eth. Birr). Numerous studies have employed linear regression model; some of which include, rainfall, air temperature, family income, etc. as independent variables (Candelieri, 2017; Bakker, et. al., 2014; Chen, et. al., 2013; Carvalho, et. al., 2012). A typical multiple linear regression model used in this analysis, to determine factors affecting the farm households' annual income intensity in (Eth. Birr) has been shown as follow:

$$\gamma_i = \beta_0 + \beta_1 \times_1 + \beta_2 \times_2 + \cdots + \beta_\rho \times_\rho + \varepsilon_\rho$$

Where γ_i denotes the predicted score of dependent variable (households' annual Log income in Eth. Birr),where: $\beta_0$denotes the intercept or the constant term and, p denotes the number of predictors, $\beta_1 - \beta_\rho$ are the coefficients relating the p explanatory variables to the variables of interest (weights or partial regression coefficients for predictors/slope), $\times_1 - \times_\rho$denote scores of predictors, and $\varepsilon_\rho$denotes errors of prediction. Positive and negative regression weights reflect the nature of correlations between predictor and dependent variable. So, multiple linear regression can be thought of an extension of simple linear regression, where there are p explanatory variables, or simple linear regression can be thought of as a special case of multiple-linear regression, where p=1. The term 'linear' is used because in multiple linear regressions, it is assumed that; y is directly related to linear explanatory variables.

3.3.4.7. Dependent and independent variables description used in farm HHs' aggregate income status

Dependent variable description:

The dependent variable (farm households' aggregate income status) has two categories (dichotomous) that include households with income equal and above the minimum standard (3781 Eth. Birr) per adult equivalent person per annum, represented by (1); and households with income below the minimum standard (3781 Eth. Birr), represented by (0).

Independent variables description:

The independent variables hypothesized to be used in this analysis, farm households aggregate food availability status were 20 (7 continuous and 13 non-continuous explanatory variables) as their list is indicated in Table 13. The detail description of these explanatory variables has presented in the Annex 1.7 for further information.

Table 13. List of independent variables used in the analysis of farm households' aggregate income status

Independent variables used to analyze farm HHs' aggregate income status	Continuous/non-continuous	Expected coef. sign
Household head age	Continuous	-
Household head formal education in years of schooling	Continuous	+
Household's size in Adult Equivalent	Continuous	-
Household's Livestock size in (TLU)	Continuous	+
Household's farm land size (Ha)	Continuous	+
Household's home distance from market (Km)	Continuous	-
Household aggregate food availability (Kcal)	Continuous	+
Household's head sex	Non-continuous	+
Households' fertilizer adoption	Non-continuous	+
Household's adoption of compost	Non-continuous	+
Household's weedicide adoption	Non-continuous	+
Household's adoption of frequent plow	Non-continuous	+
Household's adoption of frequent weeding	Non-continuous	+
Household's adoption of improved seed	Non-continuous	+
Household's adoption of farm drainage	Non-continuous	+
Household's access to formal credit	Non-continuous	+
Household's off-farm participation	Non-continuous	+
Household's access to agricultural extension service	Non-continuous	+
HH's participation in improved livestock production	Non-continuous	+
HH's participation in barley output market options	Non-continuous	+

Source: own organization

Econometrics model specification used in farmers' income status (Binary Logit Model)

To analyze highland barley farm households' aggregate income status and its determinants, binary logit regression model has been employed. In this analysis, the Ethiopian CSA and WFP (2014) guideline has been used that describes "the farm households with income below (Eth. Birr. 3781) minimum income standard per annum per adult equivalent person are considered as the households' with income status below the minimum income standard; while others whose income status equal and above the minimum standard are considered as the households with income status equal and above the minimum income standard per annum per adult equivalent person". As a result, for the analysis, those households with income below the minimum standard are represented by (0); and those with income equal and above the minimum standard are represented by (1). Moreover, in this analysis, to identify determinants that are expected to affect farm households' income status, binary logit regression model has been selected and used; and the model specification has been given here in below.

According to, Liao (1994) and Gujarati (1995), non-linear probability model (logit/probit) model can be used to estimate dependent dichotomous variable, since linear probability model is not appropriate to test the statistical significance of estimated coefficients. In Logit model, the estimated probabilities increase but never steps outside 0–1 interval and the relationship between probability (Pi) and explanatory variable (Xi) is non-linear. Although Probit and Logit model are almost similar, commonly due to its estimation and interpretation, Logit model is used widely. As a result, Logit model is selected and employed in this study. The functional form of logit model is specified as follows, according to Gujarati (1995);

$P_i = E\left(Y = \frac{1}{X_i}\right) = \frac{1}{1+e^{-(\beta_0+\beta_i X_i}}$.. (1)

For ease of exposition, we write (1) as: -for the occurrence/existence

$P_i = 1/1 + e{-}Z_i$ .... (2)

For the probability of absence, we can write:- 1-P_i=1/1+e^{Z_i} ....(3)

Therefore, we can write:- $\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i}$..(4)

Now, (Pi/1-Pi) is simply the odds ratio, which indicates that the ratio of the probability that a household will be equal or above the minimum income and food available status to the probability that the household will be below the minimum income and food available status.

Finally, taking the natural log of equation we obtain:

L_i=ln[$\frac{P_i}{1-P_i}$] = $Z_i = \beta_0$+$\beta_i X_i$+β_2+......+$\beta_n X_n$..(5)

Zi = is a function of n explanatory variables (x) which is also expressed as:

Z_i= β_0+$\beta_i X_i$+$\beta_2 X_2$+.....+$\beta_n X_n$..(6)

$\beta_0$is an intercept; β_1, β_2......β_n are slopes of the equation in the model.

Li = is log of the odds ratio, which is not only linear in Xi but also linear in the parameters

Xi = is vector of relevant household characteristics

If the disturbance term (Ui) is introduced, the logit model that has been used to analyze determinants of HHs' income and food availability in this study becomes;

$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + U_i$..(7)

3.3.4.8. Description of farmers' intensity of barley food availability determinants and analytical regression models specification

Dependent variables description: The dependent variable, farm households' (intensity of food availability from barley) is a continuous variable measured in (kcal). The independent variables that are expected to affect/influence the dependent variable are listed in Table 14; and their detail description for further information has presented in Annex 1.8.

Independent variables description: The independent variables, hypothesized to affect the dependent variable, farm households' intensity of food availability from barley. The total independent variables selected for this study were twenty (20), among which (6 continuous and 14 non-continuous) were included in the model for further analysis after conducting a test for multicollinearity problem.

Table 14. Description of farm households' intensity of barley food availability determinants

Independent variables affecting the intensity of barley food availability at HH level	Continuous/Non -continuous	Expected Coef. Sign
Household head age (years)	Continuous	-
Household head formal education (years of schooling)	Continuous	+
Farm Land size (Ha)	Continuous	+
Household size (Adult equivalent)	Continuous	+
Household Livestock size (TLU)	Continuous	+
Annual Income (Eth. Birr)	Continuous	+
Household head sex	Non-continuous	+
Households' fertilizer adoption	Non-continuous	+
Household's adoption of compost	Non-continuous	+
Farm household's weedicide adoption	Non-continuous	+
Household's adoption of frequent plow	Non-continuous	+
Farm household's adoption of frequent weeding	Non-continuous	+
Household's adoption of improved seed	Non-continuous	+
Household's adoption of farm drainage	Non-continuous	+
Farm house holds formal credit access	Non-continuous	+
Farm households' access to barley extension service	Non-continuous	+
Household participation in barley selling options	Non-continuous	+
Households participation in *Belg* production	Non-continuous	+
Farm household's participation in Land Rent-in practice	Non-continuous	+
HHs' participation in rain-fed crop irrigation support	Non-continuous	+

Source: own organization

Econometrics regression model specification (Censored Tobit Model) used to analyze intensity of barley food availability at household level

The econometrics regression model (censored Tobit regression model) was selected and employed to analyze factors affecting the farm household's food availability intensity from barley. The model reveals both the probability and intensity of barley food availability. Following Amemiya (1985), Maddala (1992);Johnston and Dinardo (1997). The Tobit model specification has given as follow:

Yi* =bXi+ *i u* i = 1, 2…………….. n
Yi = Yi* if Yi* > 0 ………………………………………………………………. (1)
= 0 if * £ 0 *i Y*

Where,

Yi = the observed dependent variable, in our case proportion of area allocated to ISM

Yi* = the latent variable which is not observable

Xi = vector of factors affecting adoption and intensity of technology use

βi = vector of unknown parameters

μi = residuals independently & normally distributed with mean zero and common variance σ^2.

The threshold value in the above model is zero, which is not a very restrictive assumption, because the threshold value can be set to zero or assumed to be any known or unknown value (Amemiya, 1985). The above Tobit model is also called a censored regression model because it is possible to view the problem as one where observations of Y* at or below zero are censored (Johnston and Dinardo, 1997). The model parameters are estimated by maximizing the Tobit likelihood function of the following form (Amemiya, 1985 and Maddala, 1997).

$$L = \prod_{yi^*>0} \frac{1}{\sigma} f\left(\frac{Y_i - \beta_i X_i}{\sigma}\right) \prod_{Yi^* \le 0} F\left(\frac{-\beta_i X_i}{\sigma}\right) \quad (2)$$

Where f and F are respectively, the density function and cumulative distribution function of Y_i^*. $\prod_{Y_i^* \le 0}$ means the product over those i for which $Y_i^* \le 0$, and $\prod_{Y_i^* > 0}$ means the product over those i for which $Y_i^* > 0$.

It may not be sensible to interpret the coefficients of a Tobit in the same way as one interprets coefficients in an uncensored linear model (Johnston and Dinardo, 1997). Hence, one has to compute the derivatives of the estimated Tobit model to predict the effects of changes in the variables. According to Johnston and Dinardo (1997) and Nkonya et al. (1997), McDonald and Moffit (1980) proposed the following techniques to decompose the effects of explanatory variables into intensity of income from barley in this particular study, where there are farm households who have not income from barley. Thus, a change in Xi (explanatory variables) has two effects. It affects the conditional mean of Yi* in the positive part of the distribution, and it affects the probability that the observation will fall in that part of the distribution. In this study similar approach has employed as indicated here in below:

The marginal effect of explanatory variable on the expected value of dependent variable is:

$$\frac{\partial E(Y_i)}{\partial X_i} = F(z)\beta i \qquad (3)$$

Where, $\frac{\beta_i X_i}{\sigma}$ is denoted by z, following Maddala, (1997)

2. Change in barley food availability intensity as independent variable Xi change is:

$$\frac{\partial F(Z)}{\partial X_i} = f\ (z)\frac{\beta_i}{\sigma} \qquad (4)$$

3. change in intensity of barley food availability where there is change in explanatory variable is:

$$\frac{\partial E(Y_i / Y_i^* > 0)}{\partial X_i} = \beta_i\left[1 - Z\frac{f(z)}{F(z)} - \left(\frac{f(z)}{F(z)}\right)^2\right] \qquad (5)$$

Where, F(z) is the cumulative normal distribution of Z that f(z) is the derivative value of normal curve at a given point (i.e., unit normal density), Z is the z-score for the area under normal curve, β is a vector of Tobit maximum likelihood estimates and σ is the standard error of the error term. The model output for this analysis is presented in result and discussion section of this study.

3.3.4.9. Dependent and independent variables description in farm HHs' (intensity of aggregate food availability) determinants

Dependent variable description:

The dependent variable, farm households' intensity of aggregate food availability is a continuous variable that measured in (kcal), based on the minimum daily requirement (threshold) for adult person, which is 2550 Kcal, according to CSA and WFP (2014). The dependent variable in this study is expected to be affected/influenced by various explanatory variables that their list and description are given here in below.

Independent variables description:

The independent variables are those variables hypothesized to affect the dependent variable (in this case the highland farm households' intensity of aggregate food availability) are listed in the Table 15. In this analysis, a total of twenty (20) explanatory variables (6 continuous and 14 non-continuous) were selected and entered in the model to determine their effects on the dependent variable. Before running the model, the test for the existence of multicollinearity were conducted. The detail description of independent variables has presented in the Annex 1.9.

Table 15. Description of independent variables hypothesized to affect farm households' intensity of aggregate food availability (Kcal)

Independent variables affecting the aggregate intensity of farm households' food availability (Kcal)	Continuous/Non-continuous	Expected coef.sign
Household head age (years)	Continuous	-
Household head formal education (years of schooling)	Continuous	+
Household size (Adult. equiv.)	Continuous	-
Households' livestock ownership (TLU)	Continuous	+
Farm land size (Ha)	Continuous	+
Household income (Eth. Birr)	Continuous	+
Household head sex	Non-continuous	+
Households' fertilizer adoption	Non-continuous	+
Household's weedicide adoption	Non-continuous	+
Farm household's adoption of compost	Non-continuous	+
Household's adoption of frequent plow	Non-continuous	+
Household's adoption of frequent weeding	Non-continuous	+
Household's adoption of farm drainage	Non-continuous	+
Household's adoption of improved seed	Non-continuous	+
Household's access to formal credit	Non-continuous	+
Household's access to agricultural extension service	Non-continuous	+
Household's participation *Belg* production	Non-continuous	+
Household's Land-rent-in participation	Non-continuous	+
Household's participation in barley selling options	Non-continuous	+
HH's participation in barley value addition practices	Non-continuous	+

Source: own organization

Econometrics Regression Model Specification (Multiple Linear Regression Model) to analyze farm households' intensity of food availability (Kcal)

To identify determinants affecting the dependent variable, the highland farm households' intensity of aggregate food availability (Kcal), multiple linear regression model was employed. In a linear regression model, the variable of interest (dependent variable) is predicted from k other variables (the so-called independent variables) using a linear equation model. If Y denotes the dependent variable, and $X_1 - X_k \ldots$, are the independent variables, then the assumption is that the value of Y at time t (or row t) in the data sample is determined by the linear equation;

$$\gamma_t = \beta_0 + \beta_1 \times_{t1} + \beta_2 \times_{2t} + \cdots .. + \beta_k \times_{kt} + \varepsilon_t$$

Where the Betas are constants and the epsilons are independent and identically distributed in normal random variables with mean zero. β0 is the so-called *intercept* of the model—the expected value of Y when all the X's are zero—and βi is the *coefficient* (multiplier) of the variable Xi. The betas together with the mean and standard deviation of the epsilons are the *parameters* of the model. The expected value of Y is a linear function of the *X* variables. This means: if Xi changes by an amount ΔXi, holding other variables fixed, then the expected value of Y changes by a proportional amount βiΔXi, for some constant βi (which could be positive or negative number, or they are fixed and unknown). The value of βi is always the same, regardless of values of the other X's. The total effect of the X's on the expected value of Y is the sum of their separate effects. The basic idea of regression is to estimate the population parameters from a given sample. The model output of the analysis for this section is given in the result and discussion section.

3.3.4.10. Dependent and independent variables description and model specification in farm households' aggregate food availability status determinants

Dependent variable description:

The dependent variable (farm households' aggregate food availability status) is the non-continuous variable that has two dimensions (dichotomous) that include (below, and equal/above the minimum standard 2550 Kcal Per day per adult equivalent person (CSA and WFP, 2014). The value one (1) is with available food Kcal (2550); and farm households with food availability status below the minimum standard is represented as Zero (0).

Independent variables description:

Independent variables expected to affect dependent variable (the highland farm households' aggregate food availability status) are seventeen (17) classified into (continuous and non-continuous predictors). The continuous ones were seven (7); and the non-continuous explanatory variables were ten (10) as indicated in the Table 16. However their detail description for further information has given in the Annex 1.10.

Table 16. Independent variables used in aggregate food availability status of farm households

Explanatory Variables	Continuous/ non-continuous	Expected Coef. sign
Household head age	Continuous	-
HH head formal education (years of schooling)	Continuous	+
Household size (Adult Equivalent)	Continuous	-
Household's Livestock size (TLU)	Continuous	+
Household's farm land size (Ha):	Continuous	+
Household's income in Eth. Birr:	Continuous	+
HH's home distance from market (Km)	Continuous	-
Household's head sex	Non-continuous	+
Households' fertilizer adoption	Non-continuous	+
Household's adoption of compost	Non-continuous	+
Household's weedicide adoption	Non-continuous	+
Household's adoption of frequent plow	Non-continuous	+
Household's adoption of frequent weeding	Non-continuous	+
Household's adoption of improved seed	Non-continuous	+
Household's adoption of farm drainage	Non-continuous	+
Household's access to formal credit	Non-continuous	+
HH's access to agricultural extension service	Non-continuous	+

Source: own organization

Econometrics regression model specification (Binary Logit Model)

In highland barley farm households' aggregate food availability status analysis to identify determinants, binary logit regression model was employed. In this study the dependent variable is, the farm households' aggregate food availability status based on the minimum requirement per day per adult equivalent analysis, which is 2550Kcal, according to CSA and WFP (2014). As a result, those households with food availability status below the minimum standard (2550Kcal) are represented by (0); and those with food availability status equal and above the minimum standard (2550Kcal) are represented by (1). The econometrics model used in this analysis that used to identify determinants expected to affect households' food availability status, is binary logit model that its specification is given here in below.

According to, Liao (1994) and Gujarati (1995), non-linear probability model (logit or probit) model can be used to estimate dependent dichotomous variable since linear probability model is not appropriate to test the statistical significance of coefficients. Unlike linear probability model, logit model guarantees that the estimated probabilities increase but never steps/moves outside (0–1) interval and the relationship between probability (Pi) and explanatory variable (Xi) is non-linear. Although Probit and Logit models are almost similar, most commonly due to its estimation and interpretation, Logit model is used widely. As a result, Logit model is selected for this study (analysis of highland barley farm household's food availability status determinants). According to Gujarati (1995) the functional form of logit model is specified as follow that for ease of exposition, the model is written as: follow:

$P_i = 1/1 + e{-}Z_i$ ……………………………………………………..…………………. (2)

For the probability of absence, we can write: 1-P_i=1/1+e^{Z_i} …..………………………….(3)

Therefore, we can write: $\frac{P_i}{1-P_i} = \frac{1+e^{Z_i}}{1+e^{-Z_i}} = e^{Z_i}$ ……..………………..…………….……..(4)

Now, (Pi/1-Pi) is simply the odds ratio, which indicates that the ratio of the probability that a household will be equal or above the minimum income and food available status to the probability that the household will be below the minimum income and food available status.

Finally, taking the natural log of equation we obtain: -

L_i=ln[$\frac{P_i}{1-P_i}$] = $Z_i = \beta_0$+$\beta_i X_i$+β_2+..….+$\beta_n X_n$……………………………….……………(5)

Zi = is a function of n explanatory variables (x) which is also expressed as: -

Z_i= β_0+$\beta_i X_i$+$\beta_2 X_2$+….+$\beta_n X_n$…………………………………………………………….(6)

$\beta_0$is an intercept; β_1, β_2……β_n are slopes of the equation in the model.

Li = is log of the odds ratio, which is not only linear in Xi but also linear in the parameters

Xi = is vector of relevant household characteristics;

If the disturbance term (Ui) is introduced, the logit model that has been used to analyze determinants of HHs' income and food availability in this study becomes;

$Z_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + U_i$…………………….……………...……….(7)

In the model, those explanatory/independent variables described here in the above were entered, and checked for multicollinearity problem, before running the model to determine the significant predictors affecting the dependent variable. The model output of this analysis is presented in the result and discussion section of this study.

CHAPTER FOUR: DETERMINANTS OF BARLEY TECHNOLOGIES ADOPTION AND ITS CONTRIBUTION TO FARM HOUSEHOLDS' INCOME AND FOOD AVAILABILITY

4.1. Sample Households' characteristics and their distribution by the study woredas

The sample households' demographic and socio-economic characteristics that include sex, household members size/number, marital status, educational status, and oxen ownership are among others as indicated in the Table 17. As a result, out of the total (812) sample households selected for this study, the male respondents were (74.38%) and that of female respondents were (25.62%). Regarding the distribution of respondents by the respective study *Woreda*, as shown in the Table 17, out of the total sample households, (33.25%) were from *Ankober woreda*, (33.50%) were from *Basona woreda*, and (33.25%) were from *Angollela Woreda*. Regarding the marital status distribution of respondents, out of the total sample households, (72.30%) were married, and the rest (27.70%) were unmarried, divorced and widowed. Hence, out of the total sample households, (4.31%) were un-married, (9%) were divorced, and (14.40%) were widowed. Hence, the majority of respondents are married.

The sample households' and their members' size in number has summarized by category and by the study *Woreda* as indicated in Table 17. As a result, respondents with 1-3 number of household members were 37.96%, with 4-6 members were 34.24%, with 7-9 household members were 25.53%, and with 10-12 household members were 7.14%. Regarding the oxen ownership of respondents has also summarized in Table 17. Hence, out of the total (812) respondents, (15.40%) were not have oxen, (14%) were have one ox, (58%) were have two oxen, and (12.60%) were have three and above number of oxen, as indicated in the Table 17. Regarding oxen ownership that in the study area, oxen are the very important asset for the farm households. It is because, oxen are used for plowing, and oxen ownership is an indicator of the households' better economic status than non owners. Farm households who have oxen can plow more land and prepare their land well as well as, they can sow their crop on time, which help them to get better yield and improve their food supply and income status.

Table 17. Sample HHs' demographic and socio-economic characteristics by study wreda

Sample HHs' characteristics		Study Woredas			
		Ankober	Basona	Angollela	Total
Respondents' Sex	Male	208 (34.44)	191 (31.62)	205 (3.94)	604 (74.38)
	Female	62 (29.81)	81 (38.94)	65 (31.25)	208 (25.62)
	Total	270 (33.25)	272 (33.50)	270 (3.25)	812 (100)
HH size (number)	1-3 HH members	45 (20.83)	89 (41.21)	82 (37.96)	216 (27)
	4-6 HH members	151(34.24)	139 (31.52)	151 (34.24)	441 (54)
	7-9 HH members	63 (44.68)	42 (29.79)	36 (25.53)	141 (17)
	10-12 HH members	11 (78.57)	2 (14.29)	1 (7.14)	14 (2)
	Total	270 (33.25)	272 (33.50)	270 (3.25)	812 (100)
Marital status	Married	199 (33.90)	179 (30.49)	209 (5.60)	587 (72.29)
	Unmarried	8 (22.86)	17 (48.57)	10 (28.57)	35 (4.31)
	Divorced	16 (21.92)	40 (54.79)	17 (23.29)	73 (9)
	Widowed	47 (40.17)	36 (30.77)	34 (29.06)	117 (14.40)
	Total	270 (33.25)	272 (33.50)	270 (3.25)	812 (100)
Educational status	Illiterate	143 (33.26)	144 (33.49)	143 (33.26)	430 (53)
	Read & Write	56 (33)	59 (34.00)	56 (33)	171 (21)
	Formal education	71 (33.65)	69 (32.70)	71 (33.65)	211 (26)
	Total	270 (33.25)	272 (33.50)	270 (3.25)	812 (100)
HH Oxen ownership (number)	None	39 (31.20)	57 (45.60)	29 (23.20)	125 (15.40)
	One ox	49 (49.98)	38 (33.33)	27 (23.68)	114 (14)
	two oxen	165 (35.03)	139 (29.51)	167 (5.46)	471(58)
	Three and above	17 (16.67)	38 (37.25)	47 (46.08)	102 (12.60)
	Total	270 (33.25)	272 (33.50)	270 (33.25)	812 (100)

Source: computed from (2014/2015) household survey data

The respondents' educational status and the distribution by the study *woreda* has summarized in Table 17. As a result, out of the total (812) respondents, 430 (53%) were illiterate, 171 (21%) were Read and Write and 211 (26%) were have formal education. Furthermore, the mean and Std. dev., of respondents' age, formal education (years of schooling), farm land holding (Ha), grazing land holding (Ha), Livestock size (TLU), and Household size (Adult. Equiv.) have summarized as shown in Table 18. As a result, the mean age of total respondents is closer to (51) years with std. dev. (14); and the *woreda* distribution of the mean age of respondents as indicated in Table 18 is that, the mean age of respondents in *Ankober woreda* is (55.19) years, in *Basona* (48.50), and in *Angollela woreda* (48.64) years. The higher mean age of respondents was found in *Ankober woreda* as shown in Table 18.

Table 18. Sample Households' demographic and socio-economic characteristics by *woreda*

Respondents' characteristics	Estimates	Ankober	Basona	Angollela	Total
Age	Mean	55.19	48.5037	48.6407	50.7709
	Std. Dev.	14.52	13.1368	12.6500	13.79842
HH head formal education	Mean	1.14	1.7243	.9481	2.49349
	Std. Dev.	2.52271	2.6675	2.20954	1.2709
Farm land size(Ha)	Mean	.3750	.8807	1.0227	.7598
	Std. Dev.	.24997	.6114	.53133	.56258
Grazing land size (Ha)	Mean	.1321	.1736	.4321	.2451
	Std. Dev	.10693	.19663	.33702	.2135
Livestock Size (TLU)	Mean	5.3712	6.3632	7.0626	6.2659
	Std. Dev.	3.08185	4.45223	4.25328	4.03181
Household (Adu. eqv.)	Mean	3.9322	4.2665	4.1359	4.1119
	Std. Dev.	1.58383	1.76004	1.72864	1.69625

Source: computed from 2014/2015 HHs survey data

The respondents' mean educational level in years of formal education as indicated in Table 18 showed (2.50) years with std. dev. (1.271), which showed that in the study area the formal educational level is low, although it is critically important to process and use information to enhance economic and agricultural development through adoption of improved agricultural technologies. Among the study *woredas,* as the mean educational level in *Basona woreda* is a little bit higher, which was (1.72 years of schooling) than in *Ankober woreda* (1.14) and in *Angollela woredas* (1 year) as indicated in the Table 18.

The farm land and grazing land holding as indicated in Table 18, the total respondents' mean farm land holding wa 0.76 (Ha) with std. dev. (.56) and the total respondents grazing land holding was 0.25(Ha) with std. dev. (.21). The mean farm land and grazing land distribution by study *woreda,* as indicated in the Table 18, the mean farm land size in *Ankober showed* (.38 Ha), in *Basona* (.88 Ha), and in *Angollela woreda* (1.02Ha). Among which, the smallest mean farm land was found in *Ankober woreda*, the medium size in *Basona woreda* and the larger size in *Angollela woreda*. Regarding the mean grazing land ownership distribution by the study *woreda* as indicated in the Table 18, (0.13ha) was in *Ankober*, (0.17) in *Basona,* and (0.43) in *Angollela woreda.* Among these *woredas*, the larger grazing land mean was found in *Angollela*, the medium size in *Basona* and the smaller size in *Ankober worea*, which showed similar trends as observed in farm land size ownership in the study *woredas*.

The livestock size ownership, as indicated in Table 18 that the total sample households' mean livestock ownership in (TLU) is (6.27) with std. dev. (4.03). The respondents' mean livestock ownership (TLU) by the study *woreda* is (5.37) in *Ankober* (6.36) in *Basona*, and (7.06) in *Angollela woreda*. As a result, the lower mean ownership of livestock is in *Ankober*, the medium is in *Basona* and the larger mean livestock ownership is in *Angollela woreda*, which may be based on the grazing land size of each the *woreda* as shown in the Table 18. Regarding the household size in adult equivalent, as indicated in the Table 18, the total mean household size showed (4.112) with (1.70) std. dev; The *Woreda* distribution of the mean size of the sample households in adult equivalent has summarized in Table 18 that in *Ankober woreda*, it was (3.93) with std. dev. (1.584), in *Basona woreda, it was* (4.27) with std. dev. (1.76), *a*nd in *Angollela woreda* it was (4.14) with (1.73) std. dev, as indicated in Table 18, which revealed that that the less mean household size was found in *Ankober woreda* as compared to the other two study *woredas (Basona* and *Angollela).*

4.2. Barley technologies adoption and its role to farmers' income and food availability

The potential role of agriculture for economic growth has long been recognized (Byerlee, et. al., 2009). In addressing poverty, growth in agriculture is one of the most effective means (Sahu and Das, 2015). Agriculture is the strategic sector in the development of most low-income nations. Smallholder farming is undertaken by smallholder farmers, which are known as small-scale farmers that they usually have limited resources and small plot/s of land (SFB, 2015). Increasing agricultural productivity and production can be realized through use of agricultural innovations/technologies (Bandiera and Rasul, 2002, 2010; and Simtowe, 2011). Agricultural technology is the most important force in increasing agricultural productivity, if it is adopted in production (Shideed and Mourid, eds., 2005). Agricultural technology adoption, according to Carr (1999), is the stage of selecting a technology and use. However, the yield of agriculture in developing countries have lagged far behind the developed countries due to underutilization of improved agricultural technologies (Aker, 2011).

Adoption of improved agricultural technologies has taken as an important route to be out of poverty (Simtowe, et. al., 2011). Improved agricultural technologies are one of the resources in agricultural production that can be reached farmers through technology transfer (Kinyangi, 2014). According to Valera et al., (1987), technology transfer is the process of moving information, knowledge and skills from the sources to the clients (farmers). The outcome of the new technology transfer is adoption and bringing the technology into practice and further diffusion to other individuals in the community. The innovation decision model of Rogers (1983) shows the process that individual or other decision making unit passes from the first awareness of the presence of innovation to forming of an attitude towards the innovation, to a decision to adopt or reject, to implement the new idea, and to get confirmation.

Adoption of improved technologies in agriculture is vital to people in developing countries who derives their livelihoods from agricultural production (Feder, *et. al.,* 1985). In developing countries, agricultural innovations are perceived as significant pathways out of poverty (Mwangi and Kariuki, 2015; Simtowe, et. al. 2011). The study by Winters et al., (1998); Mwabu et al., (2006); Wu et al., (2010) showed the positive impact of agricultural technologies adoptions on poverty reduction. The decision to adopt a new or improved technology/practice can be regarded as an investment decision. It is because of the potential capability of the new technology in terms of enhancing yield, reducing cost of production and give rise to higher profit. In Sub-Saharan African countries where agriculture is the predominant sector that supports the livelihood of the majority of the poor, technology adoption has the potential contribution in economic growth and poverty reduction. The adoption of improved agricultural technologies is needed to improve agricultural productivity to alleviate food insecurity (Obisesan, 2015).

Adoption of improved agricultural technologies has been associated with higher earnings, lowering of poverty, improved nutritional status, and lower staple food prices, increasing employments (Ghimire, *et. al.,* 2015; Kassie, *et al,* 2011; de Janvry and Sadoulet, 2001 and 2002; Binswanger and von Braun, 1991). Multiple factors responsible in adoption of agricultural technologies, include the characteristics (attributes) of the technology, adopters, change agents (extension workers and professionals), socio-economic factors, biological and physical environment. According to Rogers (1983), the characteristics of technology are important determinants of adoption in addition to the characteristics of farmers' age, household size, farm size, education, experience and the farming enterprises. Empirical studies indicated that dissemination and adoption of better agricultural technologies can reduce poverty and food insecurity in SSA (Shiferaw et al., 2008; Kijima et al., 2008).

A study conducted by Muzari, *et.al.,* (2012) in Sub-Saharan Africa on the impacts of technology adoption on smallholder agricultural productivity found out that technology adoption influencing factors were categorized as assets, income, institutions, vulnerability, awareness, labor and smallholders' innovativeness. Agriculture is the major sector for Ethiopian economy. It contributes for about 43% of nations' GDP, a leading source of jobs for 75-83% of the population, and 90% of the foreign exchange earnings and it provides about 70% of the county's raw material requirement for large and medium scale industries (MOARD, 2009; MOFED, 2013). In 2007, about 70 % of all land under crops was used for cereal production (CSA, 2009). In Ethiopia, over 95% of agricultural output originates from smallholders, despite their major contribution to the country's economy. Smallholder farmers in Ethiopia, are characterized by limited access to inputs, output markets, and low productivity (Gebremedhin et al., 2009; CSA, 2009).

Accelerating agricultural growth is one of the objectives in less developed countries, such as Ethiopia, where agricultural productivity is low. Understanding of the determinants of technological change in agriculture is vital to design development policies and alleviate poverty and chronic food insecurity (Leggesse, *et. al.*, 2004). Now days, in rural Ethiopian, at least three diploma holder agricultural extension workers in (crop production, livestock production, and in natural resource management and development) are assigned per rural *Kebele* in most of the rural *kebeles* of the country. Furthermore, based on the potential of the rural areas, other professionals such as cooperative, animal health and irrigation professionals are assigned in addition to provide technical supports for the farming community. As a result, farm households in most part of the country have accesses and acquaintances with various types of agricultural technologies, although studies in this regard are scarce.

In the study area in (*Ankober*, *Basona*, and *Angollela*) *woredas* where this study was conducted, farm households adopted various agricultural technologies in their barley production. Among many barley technologies adopted by the farm households in the study area, the most important ones include (barley farm land frequent, frequent oxen plowing three or more times, chemical fertilizer, manure compost, frequent hand weeding of barley two or more times, weedicide, barley farm land drainage, improved barley seed varieties, and improved farm tools). However, although several agricultural technologies are adopted by the farm households in their barley production in the study area, studies on the determinants of adoption of these technologies, their contributions on farm households' income and food availability, on farm households and on farm households' perception towards extension service as regard to adoption of improved agricultural technologies, thereby, to improve farm households' income and food availability.

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Cereals provide energy and protein for about two third of world's population. In Ethiopia, according to Alemayehu, *et. al.*, (2011), cereals in Ethiopia are grown on 73.4 % of the total farm land area cultivated during 2004/2005-2007/2008. After cereals, the 2nd most important crop group in Ethiopia is pulses grown on 12.4% of cultivated land area, which followed by Oil seeds grown on 6.9 %of total cultivated land area. Coffee, accounting for 3.8 % of GDP, occupied 2.7 % of total cultivated area, Chat, and other stimulant crop, cultivated on 1.3% of total area cultivated, and it accounted for 5% of total export earnings. Vegetables and root crops were cultivated on 2.6% of total area cultivated. Furthermore, agricultural production in Ethiopia varies widely across agro ecological regions that include, (i) the moisture-reliable cereal areas, (ii) moisture-reliable *enset* areas, (iii) the humid lowlands, (iv) drought-prone highlands, and (v) pastoralist areas. Most smallholder farms are located in the moisture-reliable cereal-based highlands, which accounts for 59% of all farm land area.

Among cereals, Barley (Hordeum vulgare) is among the important cereal crops cultivated in Ethiopia. It occupies 1.02 million hectare of land, approximately represents (11%)of cultivated crop area, and is ranked 5th in terms of production area (CSA, 2013; Yosef, *et. al*., in Mulatu and Grando, 2011). It is nutritionally superior in providing essential nutrients in biologically available forms. Barley is a staple food crop for many Ethiopians, especially for highlanders. It grows best at the higher elevations in the northern and central regions of the country (Kaso and Guben, 2015). Barley is thought to have originated in the Fertile Crescent area of the Near East from the wild progenitor Hordeum spontaneum. It is one of the first cereals to have been domesticated, having been cultivated for more than 10 000 years. Ethiopia is considered as one of the areas where barley was grown in earlier times (Lev-Yadun et al. 2000; Bayeh and Berhane, in Mulatu and Grando, 2011).

In Ethiopia, the long cultivation history and the diverse agro-ecologies and cultural practices have resulted in a wide range of barley diversity (Firdissa, *et. al.*, 2010). There are two barley varieties in Ethiopia (food barley for human consumption and malt barley that can be converted into malt; a key ingredient in beer making). Malt barley in Ethiopia has dual purpose that it can be used for food (bread and different traditional dishes) and malting (USDA, 2014). Food barley is cultivated in stressed areas where soil erosion, drought or frost limits other crops ability to grow (Berhanu, *et. al.,* 2005). However, malting barley requires favorable environment (Fekadu, *et. al.,* 2002). Ethiopia ranked twenty-first in the world in barley production with a share of 1.2% of the world's total production (USDA, 2014); and the second largest barley producer in Africa, next to Morocco, accounting for about 25% of the total barley production in the continent (FAO, 2014). Barley is cultivated in Ethiopia under no or little external inputs (fertilizer or chemicals to control pests). Barley in Ethiopia has a wide range of uses that its grain is used (i) as a staple food, (ii) for malting and local drinks making, (iii) sold for cash; and (iv) the straw and stem stubs of barley are used for animal feed and thatching (Takele, *et. al*., in Bayeh and Grando, 2006).

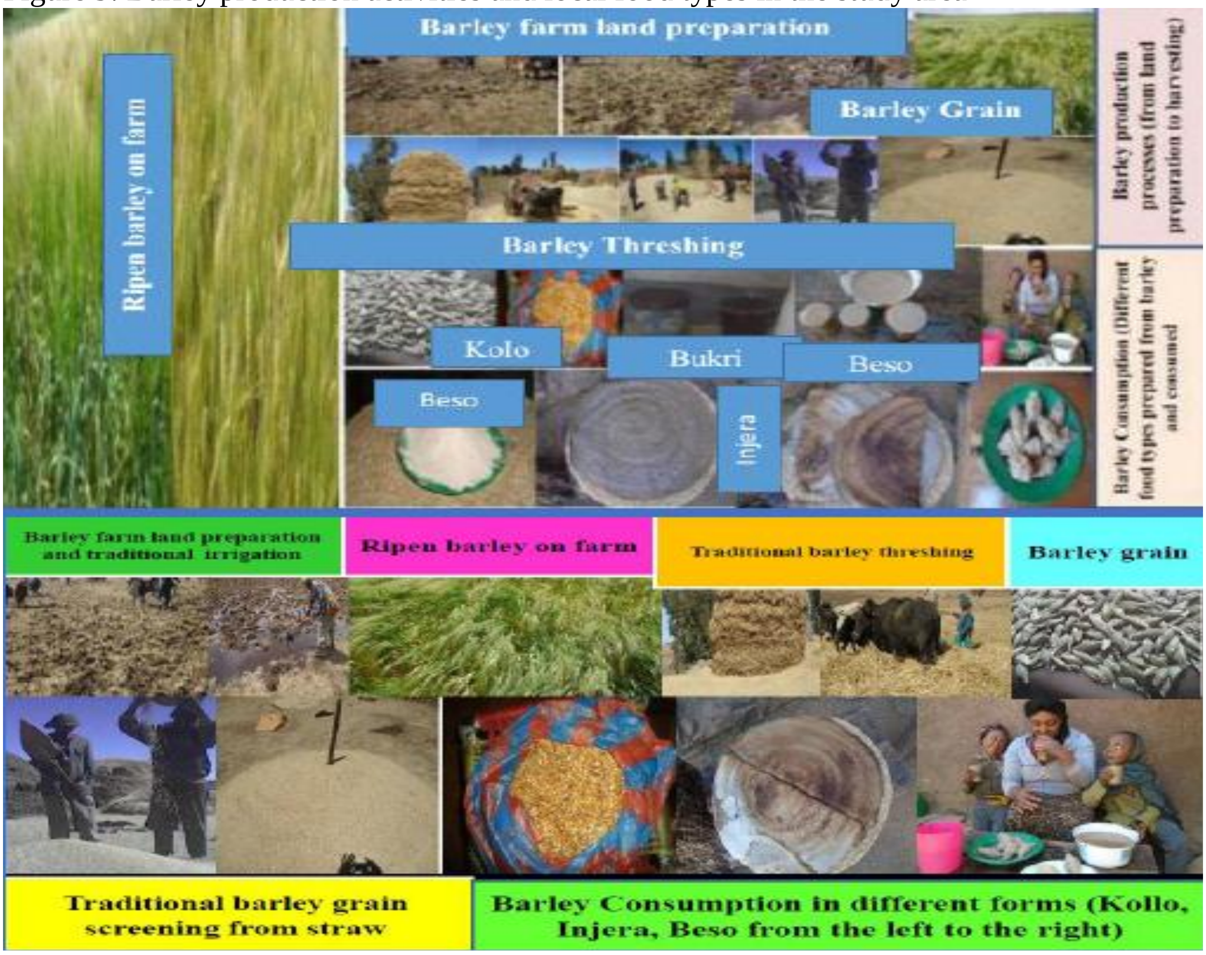
For resource-poor highland farmers where poor soil fertility, frost, water logging, soil acidity and soil degradation are the major yield limiting factors, and where other cereals fail to grow, barley is the most desirable and preferable cereal crop (Firdissa, *et. al.,* 2010). It is preferred by subsistence farmers because of its ability to grow on marginal farms, unlike other cereals (Vavilov, 1951, Qualset, 1975, Bonman, *et al.,* 2005). In Ethiopia, barley grain is produced mainly for human consumption and it is one of the most important staple food crops (Birhanu *et al*., 2005). Unlike in industrialized countries where barley is mainly used for animal feed and malting, it is one of the staple food crops in Ethiopia, accounting for 6% of the per capita calorie consumption (Alemayehu, *et. al.,* 2011).

Furthermore, barley's straw is used as feed for cattle during dry seasons. Barley is the fifth most important cereal crop after *teff,* wheat, corn, and sorghum. It is the staple food grain for Ethiopian highlanders. However, the productivity of barley in the country has been stagnant for a long time due to high soil degradation and low farm input supplies such as fertilizer and improved seed (Abu and Gray, 2013). In the main agricultural regions of Ethiopia, there are two production and rainy seasons (the *meher* and *Belg* seasons). The *meher* season is the main production season encompasses crops harvested between Meskerem (September) and Yekatit (February). The *Belg*-season encompasses crops harvested between Megabit (March) and Nehase (August). In the *meher* production season 93 %t and in *Belg* season 4.5% of national cereal was produced by small holder farmers in 2007/08(Alemayehu, *et. al.,* 2011).

There are five barley production systems in Ethiopia, according to Chilot, et. al., (1998) that include: (i) Late production-practiced more in the high-altitude during *Meher* season, (ii) *Belg* production -practiced in North and North West *Shewa*, North Wollo, Bale and in few areas of *Arsi*. *Belg* barley is planted from February to early March and harvested nearly July. Due to moisture stress, farmers do not use fertilizer, (iii) *Guie* (soil burning) production is practiced during *Meher* season, mostly in the highlands of North and North West *Shewa*, where waterlogging is a problem, (iv) Early-production-practiced in *Meher* season and in mid and high altitude areas of *Gojam* and *Gonder*, North West Ethiopia and in some parts of *Shewa*, and (v) Residual production-it is important in some parts of *Gojam*, North and South *Gonder*, and West *Shewa*. Planting is carried out between September and October, immediately after harvesting of barley grown in *meher* season. Fertilizer is not applied in this system; and harvesting is carried out between December and February.

In the study area, in the highland of *Semen Shewa Zone*, *Amhara* region, central Ethiopia, barley is produced widely for consumption and for income. Since the study area is highland, it is more suitable for barley production. As a result, it is widely produced, consumed and used as income source by the farming community in the study area.

Figure 9. Barley production activities and local food types in the study area



Source: Photos taking and organization during survey field work

As indicated in Figure 9, barley is used for local food preparation that include (*Injera, Kita, Kinche, Genfo, Atmit, Beso, Shamet, Kolo*), and for local drink preparation such as (*Tela, Bukri/keneto*, and *Areke*) in the study area. Furthermore, it is used as the beginning food for children, which is known in Amharic, (*Atmit*), which is known liquid food for children to exercise and begin food consumption. In addition to human food and income source, barley a source of livestock feed in the form of straw, as well as for house wall construction by mixing it with mud (for mud plastering) and its stem for roof thatching of the house of the farm households. As a result, almost all of the farm households in the study area, are involved in barley production.

The farm households use different barley varieties (both local and improved varieties). Some of the local varieties by their local name, in Amharic, are *Nech Gebse, Tikur Gebse, Mawge, Sene Gebse, Ginbote*; and among improved varieties, *Baso, Agegnehu, Mulu, Holker, Beka*, are among some of them. Farm households in the study area produced barley both with and without using improved technologies. Farmers used fertilizer in the production of improved varieties. In the study area, farmers use different improved technologies and practices such fertilizer, compost/ manure, frequent plowing of barley farm land (3 and above), hand weeding of barley (2 and above), weedicide, improved seed and farm land drainage (to drain out excess water from the farm). This study as one of the objective focused and conducted to investigate the aforementioned barley technologies adoption determinants in the study area, followed by assessment of the contributions of barley technologies adoption on the farm households' income and food availability. In addition, the study was examined the farm households' perception towards agricultural extension service as regard to barley technologies adoption.

In this study, barley farm land frequent plow (three and more times plowing) is the most important and widely practiced by farm households. As a result, out of the total (812) sample households, it was adopted by (73.89%) of sample farm households; and chemical fertilizer was the second to be adopted by the farm households that, out of the total (812) sample households' chemical fertilizer was adopted by (71.80%) of sample households. However, the focus group discussion participants were explained that fertilizer adopters were not adopt based on their choices and willingness. They explained that there are direct and indirect influences on farmers to adopt fertilizer by purchasing with direct cash paying or through credit. It is because, there are people and organizations, who get benefits by selling fertilizer in cash or through credit, without taking in to account the fertilizer quality, affordability and other farmers problems and opinions.

The third widely adopted improved barley technology in the study area was manure/compost, which was adopted by 453 (55.80%), out of the total (812) sample households. Furthermore, it was confirmed by focus group discussion participants that, except the problem of scarcity compost is highly demanded in the current time. However, since it is obtained from livestock, its adequacy is the most important limiting factor to use it more widely. Its labor demand for application can be solved through group work. Regarding its benefit as confirmed during focus group discussion as the participants opinion summary indicated in Annex 5, manure compost applied once can help to improve barley yield at least for three years. It can also improve the soil mass. Frequent hand weeding of barley (two or more times hand weeding) was also the fourth improved practice adopted by (47%) of sample respondents, which is out of the total (812) sample households.

Furthermore, the other important barley technology analyzed in this study was weedicide, which ranked fifth based on the number of adopters. Adopters of weedicide, out of the total sample households were (27.46%). The other, barley technologies adopted by farm HHs were farm land drainage, improved barley seed varieties, and improved farm implements (BBM-broad bed molder, irrigation hand pump, etc.) were adopted by 223 (27.46%), by 160 (19.70%), and by 152 (18.72%) sample households, respectively, out of the total (812) sample households, which ranked based on the adopters' number, 6th, 7th and 8th, respectively.

Regarding, respondents' adoption of the number of barley technologies analysis also showed that out of the total respondents, non-adopters were 9%, one technology adopters were 5%, two technologies adopters were 12.4%, three technologies adopters were 16.30%, four technologies adopters were 22%, five technologies adopters were 14.7%, six technologies adopters were 11% and seven and more technologies adopters were 9.6%. The highest proportion of respondents were adopters of four number of barley technologies. Up to four number of barley technologies, adopters number and barley technologies adopted increase simultaneously. But after four number of barley technologies, when the number of barley technologies increase, adopters number showed to decrease. Therefore, farm households adoption showed variations in the number of adoption technologies might be due to the adopters' resource ownership, perception level, extension support, inputs costs and qualities.

Furthermore, during the focus group discussion (FGD) conducted in this study as shown in Figure 11 (Annex), the (FGD) participants explained that farm households are inclined more towards their local varieties than the new improved barley seed varieties. It is because, farm households believed that local varieties are better in many situations, such as in disease and pest resistance, frost resistance, they can give yield without fertilizer (in low soil fertility), have better food test, give better straw quality and quantity, they are better in storage, suitable to prepare local/traditional food items/types and beverages.

Furthermore, the high cost of improved seeds was the other hindrance to adopt new barley varieties. During the focus group discussion, as indicated in Figure 9, participants based on their experience, the yield obtained from local varieties and from improved varieties in the unfavorable environmental condition, local varieties showed better as compared to the improved varieties. It is because of their adaptation of the environmental condition. As was confirmed by the (FGD) participants as their opinion summary indicated in Annex 5, although research centers and office of agriculture (extension) have tried to promote improved/new barley varieties to be adopted by the farm households. However, the majority of farm households in the study area used their own local varieties. According to the focus group discussion participants, farm households in the study area preferred their local barley varieties than improved varieties because of poor resistance, poor test quality for food consumption, low straw quantity, high cost of improved barley varieties. Therefore, for better adoption, reducing prices and improving the seed quality can improve its demand.

Regarding the improved farm tools such as broad bed molder, improved irrigation pumps, and other improved farm tools, as shown in Table 19, out of 812 respondents, (18.72) were adopters of improved farm tools and the rest (81.28) were non-adopters. Among improved farm tools, broad bed molder help farm households for row plantation and drained out the excess water from farm land. In this study, out of the total respondents', (90.89%) were adopters of one or more barley technologies, while the rest (9.11%) were non-adopters, as indicated in Table 19. Among (738) adopters of one or more barley technologies (74.80%) were male and the rest 25.20% were female respondents.

Table 19. Barley technologies adoption in the study area and adopters distribution by technologies, respondents' sex and woreda

Improved technologies adoption in barley production	Barley technologies adopters distribution by respondents' sex and study woredas								Adoption level is based on adopters' number
	Adopters by sex		Adopters by *woreda*			Total adopters and non-adopters			
	Male	Female	*Ankober*	*Basona*	*Angollela*	Adopters	Non-Adopters	Total sample	
Barley farm land frequent plow	454 (75.67)	146 (24.33)	197 (32.83)	226 (37.67)	177 (29.50)	600 (73.89)	212 (26.11)	812	Technologies adopted by more than 50% of adopters
Fertilizer adoption	441 (75.64)	142 (24.36)	136 (23.33)	210 (36.02)	237 (40.65)	583 (71.80)	229 (28.20)	812	
Manure compost	348 (76.82)	105 (23.18)	131 (28.92)	193 (42.60)	129 (28.48)	453 (55.79)	359 (44.21)	812	
Frequent hand weeding of barley	278 (72.77)	104 (27.23)	169 (44.24)	121 (31.68)	92 (24.08)	382 (47.04)	430 (52.96)	812	Technologies adopted by 40-50% adopters
Weedicide	259 (75.51)	84 (24.50)	145 (42.27)	125 (36.44)	73 (21.28)	343 (42.24)	469 (57.76)	812	
Barley farm land drainage	172 (77.13)	51 (22.87)	33 (14.80)	63 (28.25)	127 (56.95)	223 (27.46)	589 (72.54)	812	Technologies adopted by less than 30% of adopters
Improved barley seed adoption	123 (76.88)	37 (23.12)	49 (30.63)	73 (45.63)	38 (23.75)	160 (19.70)	652 (80.30)	812	
Improved farm tools	117 (76.97)	35 (23.03)	42 (27.63)	32 (21.05)	78 (51.32)	152 (18.72)	660 (81.28)	812	

Source: own organization from household survey (2014/2015); and numbers in parentheses represent percent;

The adopters' distribution by the study *woreda*, as indicated in Table 20, out of (738) total adopters, (31.30%) were from *Ankober*, (35.10%) were from *Basona*, and (33.60%) were from *Angollela woreda*, which revealed that adopters' distribution by the study *woredas* in total technologies adoption showed that, almost there were equal adopters number in each study *woreda* as indicated in Table 19, although there were variations in each barley technologies adopters' number (proportion).

Furthermore, As shown in Table 19, among the mentioned technologies, the least adopted technology based on adopters' number was improved farm tools. Regarding the male and female adopters, as shown in the Table 20, among (604) male sample households, (91.39%) were adopters, and among (208) female sample households, (89.42%) were adopters, which revealed that, adopters showed higher proportion (number) than non-adopters in both male and female adopters. The distribution of adopters and non-adopters with in the study *woredas* as indicated in Table 20, out of (270) sample households in *Ankober woreda*, adopters were 85.56%, in *Basona* 95.22% and in *Angollela* 91.85%. As a result, in all the three study *woredas*, adopters' number (proportion) is higher as compared to non-adopters. However, among the three study *woredas*, adopters in *Ankober* were less than the two *woredas*, which was 85.56%, which may be due to the steepness of the land in the *woreda*, low extension service, distance from the main road and main Zonal market center.

Table 20. Adopters and non-adopters' sample households' characteristics distribution

Adopters and Non-adopter respondents' distribution		Adopters and Non-adopters' distribution		
		Adopters	Non-adopters	Total sample HHs
Male and female sample HHs	Male HHHs	552 (91.39)	52 (8.61)	604 (74.38)
	Female HHHs	186 (89.42)	22 (10.58)	208 (25.62)
	Total	**738 (90.89)**	**74 (9.11)**	**812 (100)**
Study area (*Woredas*)	Ankober	231 (85.56)	39 (14.44)	270 (33.25%)
	Basona	259 (95.22)	13 (4.78)	272 (33.50%)
	Angollela	248 (91.85)	22 (8.15)	270 (33.25%)
	Total	**738 (90.89)**	**74 (9.11)**	**812 (100)**
Respondents' perception category to extension	Low	27 (13.78)	169 (86.22)	196 (24.14)
	Medium	43 (81.13)	10 (18.87)	53 (6.53)
	High	526 (93.43)	37 (6.57)	563 (69.33)
	Total	**738 (90.89)**	**74 (9.11)**	**812 (100)**
Sample HHs' frequent contacts with DAs	No contact	54 (75)	18 (25)	72 (8.87)
	Once in a month	577 (92.17)	49 (7.83)	626 (77.10)
	Twice contacts	98 (95. 15)	5 (4.85)	103 (12.68)
	Three and above	9 (81.82)	2 (18.18)	11 (1.35)
	Total	**738 (90.89)**	**74 (9.11%)**	**812 (100)**

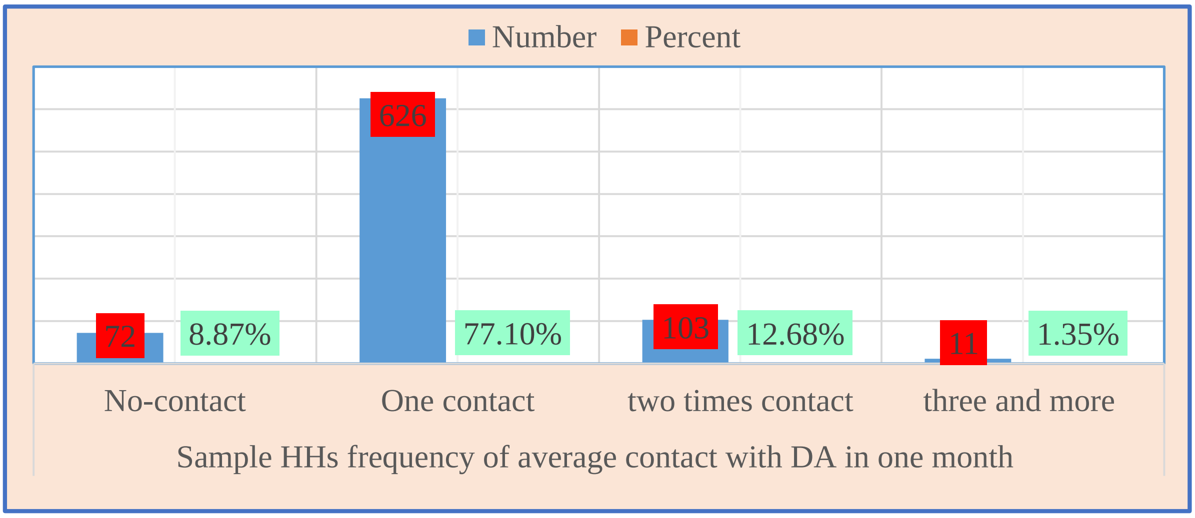
Source: own organization from household survey (2014/2015); and numbers in parenthesis represent percent

Furthermore, respondents' distribution by their perception towards agricultural extension service and by their adoption status of barley technologies has summarized in the Table 20. In this case, respondents with mean perception below 3 were grouped under low perception, those with mean perception equals to three were under medium perception and those with mean perception above 3 were grouped under high perception. Therefore, out of the total

(812) respondents, those with low perception were (24.14%), with medium perception (6.53%) and with high perception (69.33%). Hence, the majority of sample households were under high perception towards agricultural extension service.

Furthermore, the total adopter respondents were (738), and their distribution by perception level has summarized in Table 20. As a result, out of the total adopters, (3.66%) were with low perception, (5.83%) were with medium perception, and the rest (71.27%) were with high perception towards agricultural extension service. Hence, the majority of adopters were with high perception, which revealed that high extension perception can help farm households to adopt improved technologies. On the other hand, the farm households' adoption distribution by their frequency of contact with development agents has also summarized in Table 20. As shown in the Table 20, among respondents, who had contact with DAs once in a month, adopters were 92%, among those who have two contacts, 95% were adopters, and among those who have three or more contacts, adopters were 83%, which revealed that contacts with Development Agents (DAs) help farm households to get better and appropriate information about improved technologies that help them to adopt the technologies, thereby, to improve their agricultural production, income and food availability. Moreover, as indicated in Figure 10, the contact of sample households with Development Agents (DAs) has summarized.

Figure 10. Farm HHs' and DA (Development Agent) average contacts per month



Source: Organized from 2014/2015 household survey data

As a result, out of the total (812) sample households, those who have not contact were 72 (8.87%), those who have one contact within a month were 626 (77.10 %), those who have two times contact were 103 (12.68%), and those who have three and more times contacts within one month time were 11 (1.35%). In the study area, the farm households and Extension Workers/Development Agents contacts on average within a month, as shown in Figure 10, the highest contacts with in a month is two times contacts. Hence, the majority of farm households have contacts with Development Agents, to get extension supports and information, on average two times in one month.

Furthermore, out of (812) total sample households, total adopters were738 (91%). The total sample households, total adopters and non-adopters' distribution by their food availability and income statuses have been summarized in Table 21. As a result, out of the total (812) sample HHs, (34. 48%) were with food availability status below the minimum threshold (2550 Kcal); while the rest (65.52%) were with equal and above the minimum. Among (738) total adopters, 245 (33.20%) were below the minimum threshold; while the rest 493 (66.80%) were with equal and above the minimum food availability threshold (2550Kcal).

Table 21. Adopters and non-adopters' respondents' income and food availability distribution

Adopters and Non-adopter respondents' distribution		Adopters and Non-adopters' distribution		
		Adopters	Non-adopters	Total
HHs' food availability status	Below 2550 Kcal	245 (85.50)	35 (12.50)	280 (34.48)
	Equal/above 2550 Kcal	493 (92.67)	39 (7.33)	532 (65.52)
	Total	**738 (90.89)**	**74 (9.11)**	**812 (100)**
Male headed HHs food availability (Kcal)	Below 2550 Kcal	179 (87.75)	25 (12.25)	204 (72.86)
	Equal/above 2550	373 (93.25)	27 (6.75)	400 (75.20)
	Total	**552 (91.40)**	**52 (8.60)**	**604 (100)**
Female headed HHs' food availability	Below 2550 Kcal	66 (86.84)	10 (13.16)	76 (27.14)
	Equal/above	120 (90.91)	12 (9.09)	132 (24.81)
	Total	**186 (89.42)**	**22 (10.58)**	**208 (100)**
Total HHs' income status in (Eth. Birr)	Below (3781)	362 (87.44)	52 (12.56)	414 (51)
	Equal/above (3781)	376 (94.47)	22 (5.53)	398 (49)
	Total	**738 (90.89)**	**74 (9.11)**	**812 (100)**
Male HHs' Income status	Below 3781	267 (87.25)	39 (12.75)	306 (50.66)
	Equal/above 3781	285 (95.64)	13 (4.36)	298 (49.34)
	Total	**552 (91.39)**	**52 (8.61)**	**604 (100)**
Female sample HHs' income status	Below 3781 Eth. Birr	95 (87.96)	13 (12.04)	108 (51.92)
	Equal/above 3781	91 (91)	9 (9)	100 (48.08)
	Total	**186 (89.42)**	**22 (10.58)**	**208 (100)**

Source: own organization from household survey (2014/2015); and numbers in parentheses represent percent;

Regarding the income status of farm households, out of the total (812) sample HHs, (51%) were with income below the minimum threshold (Eth. Birr 3781), while the rest (49%) were with income equal and above the minimum income threshold. Furthermore, out of the total

(738) adopters of barley technologies, 49% were below the minimum food availability threshold, while the rest 51% were with income equal and above the minimum threshold (Eth. Birr. 3781), which revealed that, more than half adopters were with better income status. On the other hand, out of the total (398) sample households with equal and above minimum income status, (94.47%) were adopters, while the rest (5.53%) were non-adopters, which also revealed that among the total adopters, the majority of them were with better income status, which suggested that adoption of improved agricultural technologies is vital to improve the farm households' income status, thereby, their food security and wellbeing.

4.3. The contribution of barley technologies in farm HHs' income and food availability

In the study area, farm HHs produce barley traditionally without using improved barley technologies and practices; and by using and application of different improved agricultural technologies and practices. Among which, barley technologies and practices, barley farm land frequent plowing (three and more times), fertilizer, manure/compost, frequent hand weeding of barley (two and more times hand weeding), weedicide, barley farm land drainage improved practice, improved barley seed, and use of improved farm tools) are among others.

Table 22. Chi-square test result on the association of barley technologies and farm households' income and food availability statuses

Adopters/non-adopters of barley technologies	Sample farm households food availability status			Pearson Chi-square	
	Below (2550 Kcal)	Equal/above (2550 Kcal)	Total	χ^2 -Value	Sig.
Adopters	245 (33.20)	493 (66.80)	738 (90.89)	5.918	0.015
Non-adopters	35 (47.30)	39 (52.70)	74 (9.11)		
Total	280 (34.48)	532 (65.52)	812 (100)		
Adopters/non-adopters of barley technologies	Sample farm households Income status			Pearson Chi-square	
	Below (Eth. Birr 3781)	Equal/above (Eth. Birr 3781)	Total	χ^2 -Value	Sig.
Adopters	362 (49)	376 (51)	738 (90.89)	12.117a	.000
Non-adopters	52 (70.27)	22 (29.73)	74 (9.11)		
Total	414 (51)	398 (49)	812 (100)		

Source: own computation from 2014/2015 household survey

As a result, respondents, who use/adopt improved agricultural technologies in their barley production have got better yield that enhance their income and food supply. In addition, farm households got better straw quantity for their livestock and better barley stem for thatching their house roofs. As it is indicated in Table 22, the chi-square analysis result showed that the farm households' barley technologies adoption status and their income and food availability statuses showed significant association that households' food availability status at 5% significant level and income status with below 1% significant level as indicated in Table 22.

Furthermore, regarding the impact of barley technologies on the farm households' income (Eth. Birr), and food availability (Kcal) improvement, the two sample t-test analyses were conducted and the results showed in Table 23 and Table 24, respectively. As it is indicated in Table 23, the annual income of sample farm households who adopted barley technologies increased on average by Eth. Birr (6853.14) than non-adopters' annual income. Hence, barley technologies adoption is critically important in improving the farm household' income.

Table 23. Two sample t-test analysis result on barley technologies adoption contribution to farm households' income (Eth. Birr)

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	11493.94	883.7702	7602.479	9732.585	13255.29
Adopters	738	18347.08	517.3672	14054.88	17331.39	19362.77
combined	812	17722.53	481.9557	13733.62	16776.5	18668.56
diff		-6853.14	1658.273		-10108.16	-3598.121

diff = mean(Non-adop) - mean(Adopters) t = -4.1327
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Pr(T < t) = 0.0000
Ha: diff != 0 Pr(|T| > |t|) = 0.0000
Ha: diff > 0 Pr(T > t) = 1.0000

Source: own computation from 2014/2015 household survey data

Regarding the sample farm households' food availability status, the two sample t-test was also conducted to see the contribution of barley technologies adoption to increase farm households' food availability (Kcal). As a result, the test result has shown in Table 24 that the food availability of adopters in (Kcal) showed higher on average by 1194295 Kcal, annually than those of non-adopters' food availability.

Table 24. Two sample t-test analysis result on barley technologies adoption contribution to farm households' food availability (Kcal)

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	4732642	400478.8	3445049	3934489	5530795
Adopters	738	5926937	156577.9	4253619	5619545	6234329
combined	812	5818097	147344.9	4198682	5528875	6107320
diff		-1194295	510567.3		-2196486	-192104.1

diff = mean(Non-adop) - mean(Adopters)   t = -2.3392

Ho: diff = 0   degrees of freedom = 810

Ha: diff < 0   Ha: diff != 0   Ha: diff > 0

Pr(T < t) = 0.0098   Pr(|T| > |t|) = 0.0196   Pr(T > t) = 0.9902

Source: own computation from 2014/2015 household survey data

Therefore, barley technologies adoption is vital to improve both the income and food availability of farm households. The importance of adoption of improved barley technologies and practices was explained also by focus group discussion participants. According to the opinions of the focus group discussion participants, improved agricultural technologies and practices are very important to increase the production of barley and other agricultural productions, thereby, to increase the income and food availability statuses of farm households, and the wellbeing of the farm households. But, there are many problems related to quality, high cost, timely availability, adequacy, and credit service problem to buy, to access and use improved agricultural inputs, which need to be alleviated for better agricultural production, thereby, to alleviate food security problem and poverty.

4.4. Determinants of barley technologies adoption (multivariate probit model analysis)

In the analysis of determinants affecting multiple barley technologies adoption using multivariate probit regression model. Multivariate probit model is a generalization of probit model used to estimate several correlated binary outcomes jointly (Greene, 2012). In this study, thirteen (13) predictors were hypothesized to affect adoption of multiple dependent variables that include (adoption of fertilizer, Compost, Weedicide, Frequent plow, Frequent hand weeding, Improved barley seed, and farm land drainage practices). Predictors were included in the model and the result of the model has shown in the Table 25. Each of the dependent variable takes the dichotomous nature that if the farm HH adopt the technology or involved in the improved practice, takes the value one (1); otherwise zero (0).

Multivariate probit model was run and the result has shown each predictor's effects on each category of the dependent variable, which means one predictor may affect one or more or none of them significantly and positively or negatively, which summarized in Table 25. However, before entering the predictors in the model for further analysis using multivariate probit model, test for the existence of multicollinearity problem were conducted using Variable Inflation Factor (VIF) through stata-version 13 for continuous predictors and correlation matrix analysis for non-continuous explanatory variables. Since, the results of the multicollinearity tests showed that there were no serious multicollinearity problems, all the selected predictors were included in the model for further analysis. Regarding the predictors' description, it has been presented in Annex 1.1; and the VIF and correlation matrix results have been indicated in Table 59 and 60 (Annex), respectively. In addition, specification of multivariate probit regression model has given in the methodology section of this study.

Regarding the determinants that were presumed to affect the multiple dependent variables include household head age in year, formal education in years of schooling, HH size in adult equivalent, Livestock size in TLU, farm land in Ha, market distance in Km, HH head sex/being male or female headed household, food availability status, income status, credit access, extension service access, participation in barley selling options and in land rent-in practice. As it is indicated in the Table 25, the effect of each predictor, on each category of dependent variable has been presented.

In the first model (equation), the dependent variable is fertilizer adoption, in this model, the model analysis output has shown that, out of 13 predictors total predictors, four were statistically significant that include (farm land size, income status, access to agricultural extension service, and participation in barley selling options), which all have affected the dependent variable, fertilizer adoption, positively and significantly as were hypothesized. The findings in this study is in line with the findings of Akudugu, et. al., (2012), Mariano, et. al., (2012), Yishak and Punjabi (2011), and Ghimire, et. al, (2015); but disagreed with the findings of Mengistu, et. al., (2016), Lugandu (2013), Awotide, et. al., (2013).

Table 25. Multivariate probit model analysis results on barley technologies adoption determinants

Independent variables	Fertilizer adoption (1st Model)	Compost adoption (2nd Model)	Weedicide adoption (3rd Model)	Frequent plow adoption (4th Model)	Frequent hand weeding (5th Model)	Improved seed adoption (6th Model)	Farm land drainage (7th Model)
	Coef. and p-value sign.	Coef. and p-value sign.	Coef. and p-value sign.	Coef. and p-value sign.	Coef. and p-value sign.	Coef. and p-value sign.	Coef. and p-value sign.
AGEHHHEAD	.0011807	-.0009435	-.0019928	-.0029001	-.0084921**	-.0027407	.0018569
LIVSTOCKSIZTLU	.0004676	-.0040357	.0091467	.032672**	.0207543	-.0131194	.0441387***
FARMLANDCULT	.47891***	.025594	-.2330968**	-.1481555	-.3075208***	.0551225	.2345495**
MARKETDISTKM	.003533	-.0159419***	-.0019932	-.005051	.0005057	.0005683	.0050661
HHHFORMEDUYR	-.0222499	.0192205	-.0078995	.0273365	.0073183	.0041403	-.0271303
HHSIZEADEQIV	.0097532	.0114745	.0406296	.0281301	.0200981	-.0780677**	.0522766*
HHHEADSEX	.0901706	.1850031*	.0698768	.1035125	-.1073078	.101538	.0471141
FOODAVAILSTAT	.0197409	.2546793**	-.0773938	.0264309	.0775299	-.0629736	.0516484
INCOMESTATUS	.4002706***	.1712882*	.1628014	.2532727**	.041977	.0391281	.1474429
HHCREDACCESS	.0776268	.2361763**	.2270351**	.2315919**	.2545235**	.6137918***	-.347789***
HHACCESAGREXT	.8213534***	.409929**	.4549393***	.5875101***	.0962211	.1151618	.9793563***
BARSELLOPTIONS	.2058866**	.3563158***	.3662608***	.3088704***	.5026908***	.5627824***	.4542917***
LANDRENTINPART	.1859925	.0034099	.0137995	.0961418	-.1487016	-.2108737	-.0162673
_cons	-1.001595	-.7452304	-.8569497	-.3580392	.0036373	-.9571737	-2.599296

Source: own computation from 2014/2015 household survey data; and (*, **, ***, significant at 10%, 5% and 1% level respectively)

In the second model equation, the dependent variable is manure/compost adoption, and the explanatory variables included in the model were thirteen, as indicated in the Table 25. Among those thirteen predictors, seven were statically significance, as were hypothesized. These significant predictors include (market distance, household sex, food availability status, income status, household credit access, household access to agricultural extension service, and household participation in different barley output market options.

The coefficient signs of significant predictors, except market distance, showed positive signs that suggested the positive correlation between dependent and independent variables. The negative sign of market distance, was also as it was presumed. The negative sign was suggested the negative correlation between the dependent and independent variables. The findings in this study are in line with the findings of Akudugu, *et. al.,* (2012), Mariano, *et. al.,* (2012), Yishak and Punjabi (2011), Ghimire, *et. al,* (2015), Mengistu, *et al.,* (2016), Lugandu (2013), Awotide, *et. al,* (2013), Mengistu, *et al.,* (2016), Lugandu (2013), Awotide, *et. al,* (2013) Ghimire and Huang (2016), Sisay (2016), Bahadur and Siegfried, (2004), Martey, *et. al,* (2014), Ogada, *et. al*, (2014), Berhanu, *et.al* (2003); Zekarias (2016).

In the third equation, weedicide adoption, which is the dependent variable. In this model, out of thirteen predictors included in the multivariate probit model, four were affecting the dependent variable significantly. Those significant predictors (farm land size, credit access, extension service access, and barley selling options). Among which, farm land size has affected the dependent variable negatively at 1% significant level, which is different from what was hypothesized. It may be due to the high cost of weedicide and those with large farm size may get easily the labor access due to their larger farm ownership, then they may use labor for hand weeding or they may have easy access to credit using their large farm land as collateral and employ laborers for hand weeding. The findings of this study are in line with the findings of Akudugu, *et. al.*, (2012), Mariano, *et. al.,* (2012), Yishak and Punjabi (2011), Ghimire, *et. al*, (2015); Mengistu, *et al.,* (2016), Lugandu (2013), Awotide, *et. al,* (2013). Regarding the farm land sign, the result of this study disagree with the finding of Akudugu, *et. al.,* (2012), Mariano, *et. al.,* (2012), Yishak and Punjabi (2011), Ghimire, *et. al*, (2015).

In the fourth model of this study, barley farm land frequent plowing model (3 and more times plowing) is the dependent variable. The independent variables, included in the multivariate probit model are thirteen as indicated in the Table. Five predictors that include (livestock size, income status, credit access, access to extension service, and households' participation in barley output market) have affected the dependent variable significantly and positively as were hypothesized with the significant level (1%-5%) as indicated in the Table 25, the positive coefficient of the significant predictors showed the positive correlation between each predictor and the dependent variable. The findings of this study are in line with the findings of Akudugu, *et. al*., (2012), Mariano, *et. al.,* (2012), Yishak and Punjabi (2011), Ghimire, *et. al,* (2015) and Tesfaye, *et. al,* (2016); Simtowe, *et. al,* (2016), Sisay (2016), Ghimire, *et. al*, (2015), Mariano, *et. al.,* (2012), Mignouna, *et. al,* (2011), Akudugu, *et. al.,* (2012), Yishak and Punjabi (2011), Bahadur and Siegfried (2004), Mmbando and Baiyegunhi (2016), Oladele (2005), Toma, *et. al*. (2016); Mengistu, *et. al.,* (2016); and Mariano, *et. al.,* (2012).

In the fifth model, the dependent variable was adoption of frequent barley hand weeding; while predictors included in multivariate probit model were (13). Among which, household head age, farm land size, credit access and participation in barley selling options were affect adoption of frequent hand weeding, significantly. Among these predictors, age and farm land size affected the dependent variable negatively, while the rest positively. The negative predictor, farm land size was differently from what was presumed. Except farm land size, the coefficient sign of household head age was as was presumed. The findings of this n line with the findings of Akudugu, *et. al.,* (2012), Mariano, *et. al.,* (2012), Yishak and Punjabi (2011), Ghimire, *et. al,* (2015). The negative result of the farm land size in adoption of frequent hand weeding is in line with the finding of Mengistu, *et al.*, (2016), Lugandu (2013), Awotide, *et. al*, (2013), who concluded that farm land size showed negative and significant effect on adoption of improved technologies (proxy variable for frequent hand weeding). The study result on no-tillage by Ntshangase, *et. al.,* (2018) is in line with the finding of this study.

In the six equation, adoption of improved barley seed, the predictors, household size, credit access, and participation in different barley output selling options were affect adoption of improved barley seed significantly, among which, household size affected the dependent variable negatively and significantly, as was hypothesized. The findings in this study (except household size) that was affect adoption of improved barley seed negatively and significantly, the other predictors were in line with the findings of Akudugu, *et. al.,* (2012), Mariano, *et. al.,* (2012), Yishak and Punjabi (2011), Ghimire, *et. al*, (2015).

The finding of this study on the credit effect in adopting improved barley seed has agreed with the finding of Wakawa, *et. al*, (2015); Ombe, *et. al.*, (2014); Ogada, *et. al.,* (2014); Iheke and Nwaru (2013); Mariano, et. al, (2012); Bahadur and Siegfried (2004), Aikens *et al.,* (1975); Smale *et al.*, (1994); Shampine, (1998), Krause, *et al.* (1990), Immink and Alarcon (1993), Iheke (2006), Yishak and Punjabi (2011). However, the finding of this study shows a contrary result with the finding of diDiiro and Sam (2015), Hertz (2009), and Martey, *et. al,* (2014). In the analysis of barley technologies adoption determinants, multivariate probit model was employed. The effect of each predictor on each dependent variable (barley technology) has summarized in Table 25. The dependent variable, adoption of barley farm land drainage improved practice, in the 7th model (equation), among these (13) predictors, only six were significant in affecting the dependent variable.

The significant predictors include (livestock size, farm land size, households' size, households' participation in barley output selling options, households' credit access, and households' access to agricultural extension service) were affect the dependent variable significantly. Out of these significant predictors, credit access affected the dependent variable negatively, which could be due to the fact that when farm households' accessed to credit service, they might use the credit for other purposes and reduce their involvement in farm land drainage practice. The findings, except household credit access, were in line with the findings of Akudugu, *et. al*., (2012), Mariano, *et. al*., (2012), Yishak and Punjabi (2011), Ghimire, *et. al*, (2015), Oladele, (2005), Aman and Tewodros (2016), Simtowe, *et. al*, (2016), Leake and Adam (2015), and Berihun, *et. al.*, (2014). However, in this study, the positive effect of farm land size on adoption of farm land drainage practice showed the result contrary to the findings of Mengistu, *et. al.*, (2016), Lugandu (2013), and Awotide, *et. al*, (2013).

Regarding the mean probability of adoption of each barley technology by all adopters has summarized in Table 26. As a result, the average probability of adoption of each barley technology in barley production has estimated that probability of fertilizer to be adopted by all adopters is 72%, compost adoption 56%, weedicide adoption 42%, frequent plow (three and more times plowing of barley farm land) 74%, frequent hand weeding (two and more times frequent hand weeding of barley crop) 47%, improved barley seed adoption is 20%, and barley farm land drainage to avoid excess water out of barley farm land 28%. In this regard, the findings of this study are in line with the findings of Beyan (2016) that the likelihoods of adopter HHs' to adopt soil conservation practices, improved seed, line planting and fertilizer were 79.6%, 69.6%, 61.2% and 70.5% respectively.

Table 26. The probability estimation of individual and joint barley technologies adoption using multivariate probit model

Dependent variables	Obs	Mean	Std. Dev.	Min	Max	Rank based on the number of adopters
Fertilizer adoption	812	.7184069	.1478349	.1886778	.9906067	2nd
Compost adoption	812	.5601985	.1406398	.1473165	.9085343	3rd
Weedicide adoption	812	.4234553	.1176947	.0925433	.7659694	5th
Three (3) and above frequent plowing	812	.7393238	.1145458	.340917	.9513528	1st
Two (2) and above hand weeding	812	.4697656	.1365894	.1406945	.8440172	4th
Improved barley seed adoption	812	.2013382	.1276294	.0178139	.7178158	7th
Barley farmland drainage	812	.2775551	.1477799	.0083022	.76873	6th
Joint adoption of all technologies	812	.0191397	.0237907	.0000215	.2274993	Joint rejection is higher than joint adoption by all farm HHs
Joint rejection of all technologies	812	.0493084	.0538193	.0004678	.384091	

Source: own computation from 2014/2015 household survey data

Table 26 has also shown that the joint probability of adoption of all technologies by all farm households' was 22.8%; and the joint failure/rejection probability to adopt all technologies by all households was 0.36%. As the probability estimation of barley technologies adoption using multivariate probit model showed that among barley technologies adopted by the farm households in barley production, frequent plowing of barley farm land (3 and above times) is highly adopted/practiced by barley farm households that, followed by fertilizer and manure/ compost adoption, which all are adopted by more than 50% of farm households as indicated in Table 26. The other barley technologies adopted with the probability of greater than 40% and below 50% are weedicide and frequent hand weeding (two & more times hand weeding).

Barley technologies that were adopted with the probability of (20-30%) were improved barley seed (by 20%) and barley farm land drainage practice (by 28%). Therefore, the most widely adopted barley technology in the study area was frequent plowing that was adopted with 74% probability level; and the least adopted barley technology was barley improved seed that was adopted with 20% probability level as indicated in Table 26. Regarding the Joint adoption or rejection of barley technologies, the multivariate probit model estimation result has shown in the Table 26 that include the joint adoption probability of all the seven barley technologies by all respondents and the joint rejection probability of all the seven barley technologies by all respondents at one time.

As the model estimation has shown in the Table 26 that, the joint adoption probability of all the seven barley technologies at one time by all respondents is 2%; and the joint rejection probability of all the seven barley technologies adoption by all respondents is 5%. The joint adoption and rejection probability estimation has shown that, the joint rejection probability is higher than the joint adoption probability. The possible explanation for this could be the cost, land scarcity, labor scarcity and households' interest to adopt and to reject all the technologies, which also influenced by the need for improved technologies and improved practices and the role of extension service could be among the others important factors.

Regarding the effect of each predator on each category of dependent variable, as shown in the analysis of barley technologies adoption determinants using multivariate probit model, each predictor's role in affecting the dependent variable (adoption of barley technologies) has summarized in Table 27., showed variations by technology type, which means, each predictor has affected one or more dependent variable. Then, the predictors (household head age, household sex, food availability status, and market distance), each of them has affected only one dependent variable, each covers (14.30%), significantly as shown in the Table 27. The predictor household size in (adult equivalent) has affected two dependent variables (covers 28.57%) that include (farm land drainage and improved barley seed adoption) significantly.

The predictor, livestock size (TLU), has affected three dependent variables (covers 42.86%) that include (barley farm land frequent plow, hand weeding and farm land drainage) significantly and positively, as indicated in the Table 27. The predictor households' income status has affected three dependent variables (covers 42.86%) that include (adoption of fertilizer, compost and frequent barley farm land plowing) significantly and positively. The predictors farm land size in (Ha), has affected four dependent variables (covers57.14%) that include (fertilizer, weedicide, frequent hand weeding, and farm land drainage) significantly. The predictor, access to extension service has affected significantly the five dependent variables (covers 71.43%), out of the total seven dependent variables) that include (fertilizer, compost, weedicide, frequent plow, and farm land drainage).

Table 27. The Summary of predictors that are affecting the number of dependent variables in multivariate probit model

Independent variables	Fertilizer adoption (p-value)	Compost adoption (p-value)	Weedicide adoption (p-value)	Frequent plow adoption (p-value)	Frequent hand weeding (p-value)	Improved barley seed adoption (p-value)	Farm land drainage (p-value)	Dependent variables affected by each predictor	Dependent variables (barley technologies), used in multivariate probit model affected by each predictors
AGEHHHEAD	0.831	0.815	0.590	0.416	-0.012**	0.595	0.605	**1 (14.30%)**	Frequent hand weeding
HHHEADSEX	0.472	0.067*	0.471	0.370	0.371	0.367	0.601	**1 (14.30%)**	Manure/compost
FODAVASTAT	0.966	0.017**	0.424	0.869	0.562	0.728	0.739	**1(14.30%)**	Manure compost
MARKDISTKM	0.669	-.001***	0.543	0.285	0.743	0.781	0.579	**1 (14.30%)**	Manure compost
HHSIZADEQIV	0.927	0.680	0.176	0.484	0.610	-0.022**	0.080*	**2 (28.57%)**	Improved barley seed
LIVSTKSIZTLU	0.783	0.755	0.410	0.011**	0.064*	0.414	0.001***	**3 (42.86%)**	Frequent plow, frequent hand weeding adoption and farm land drainage
INCOMSTATU	0.001***	0.081*	0.138	0.040**	0.775	0.723	0.190	**3 (42.86%)**	Compost adoption and Frequent plow
FARMLNDHA	0.000***	0.844	-0.010***	0.111	-0.000***	0.721	0.019**	**4 (57.14%)**	Fertilizer, weedicide, frequent hand weeding and farm land drainage
ACESAGREXT	0.000***	0.014**	0.010***	0.000***	0.730	0.606	0.000***	**5 (71.43%)**	Fertilizer , Compost, Weedicide, Frequent plow, Farm land drainage
CREDACCESS	0.582	0.023**	0.026**	0.071*	0.013**	0.000***	-0.004***	**6 (85.71%)**	Compost, Weedicide, Frequent plow, Frequent hand weeding, Improved barley seed adoption, and Farm land drainage
BARSELOPTNS	0.000***	0.004***	0.000***	0.000***	0.000***	0.000***	0.000***	**7 (100%)**	Fertilizer, Compost/manure, Weedicide, Frequent plow and weeding, Improved seed and farm drainage
FORMEDUYR	0.208	0.304	0.655	0.255	0.774	0.776	0.171	**0**	Non-of these predictors are affecting the dependent variable
LADRETINPAR	0.174	0.895	0.885	0.457	0.193	0.144	0.908	**0**	
_cons	0.001	0.016	0.006	0.291	0.716	0.010	0.000		

Source: own computation from 2014/2015 household survey data

The predictor, credit access, has affected significantly the six dependent variables (covers 85.71%) that include (compost, weedicide, frequent plow, frequent hand weeding, improved barley seed, and farm land drainage); and the predictor farm household participation in barley selling options has affected significantly and positively the seven dependent variables (covers 100%) as indicated in the Table 27, which is the first and most important predictor affected all the seven dependent variables in this study.

4.5. Fertilizer adoption determinants and its contribution in farm households' income and food availability

The ultimate goal of any rural or agricultural development strategy or program is to improve the welfare of rural households. This goal is achieved among other things by increasing productivity at farm level and by raising farmer's income and by improving their welfare. This is possible if and only if improved agricultural technologies are properly transferred and disseminated to farmers so as to deepen and intensify their production (Assefa and Gezahegn, 2009). Inorganic fertilizer was introduced in Ethiopia with the objective of increasing agricultural production. The initial fertilizer demonstration was carried out during the period 1967-69. Before the introduction of inorganic fertilizer, shifting cultivation was practiced. At that time, some estates and commercial farms imported 1000-2000 metric tons of fertilizer (FAO, 1979, World Bank, 1995). Since the introduction of inorganic fertilizers, considerable efforts have been made to expand its use but the progress is not encouraging (CSA, 1997).

Fertilizer is considered the most important input for the achievement of increased agricultural productivity and food security status of farm households in Ethiopia, especially among small-scale farmers in the country. However, its adoption and application intensity by smallholders remained very low (Fufa and Hassan, 2006). Fertilizer use is one instrument implemented as a means of raising production, yield and income of farm households (Kefyalew, 2011). Agricultural growth and development is not possible without yield-enhancing technological options since expanding the area under cultivation to meet the increasing food needs of growing populations is no longer possible (Kassie, *et al.*, 2011).). Hence, Adoption of productivity enhancing technologies is crucial to increase agricultural productivity and reduce poverty (Becerril and Abdulai, 2010; Minten and Barrett, 2007). Hence, to feed the rapidly growing population, smallholder farmers need to be productive through adoption of improved agricultural technologies, such as fertilizer.

The Ethiopian economy is diversified, although it is heavily relied on agriculture as the main source of employment, income and food security for a vast majority of its population. In the country, cereals, among which teff, barley, maize, sorghum, oats, millet and wheat, make up 85% and 90% of the total cultivated area and total production of field crops respectively and accounts for over 90% of modern input consumption (CSA, 2000; MEDaC, 1999). However, the sector is characterized by low productivity and prevalence of fragmented smallholder/ subsistence farming population that is relegated to highly degraded/marginal lands (World Bank, 2010). Crops production, especially cereals are very low because of low utilization of improved inputs, such as fertilizer (CSA, 2009b). In this study, regarding fertilizer adoption, out of (812) total sample HHs' (71.80%) were fertilizer adopters, while the rest (28.20%) non-adopters. Among total (583) fertilizer adopters of sample households, (75.64%) were male, and (24.36%) were female adopters.

Regarding adopters' distribution by the study *woreda* as indicated in Table 28, (23.33%) were from *Ankober*, (36.02%) were from *Basona* and (40.65%) were from *Angollela woreda*, which revealed that the higher proportion of adopters were from *Angollela woreda* that followed by *Basona* and *Ankober woreda.* Furthermore, the fertilizer adopters' distribution by the quantity of fertilizer they adopt has summarized as indicated in the Table 18. As a result, adopters below one quintal (100Kg) fertilizer were (117), out of which, (76.92%) were male adopters and (23.08%) were female adopters; their *woreda* distribution is that (44.44%) were from *Ankober*, (30.77%) were from *Basona*, and (24.77%) were from *Angollela,* which revealed that the larger proportion of adopters below one quintal (below 100Kg) were from *Ankober woreda*. Adopters of one quintal (one 100Kg) fertilizer, and their distribution by the adopter households' *woreda* and household head sex, has summarized in the Table 28. As a result, out of the total (211) one quintal (100Kg) fertilizer adopters, (75.64%) were male and (24.36%) were female. Regarding their distribution by *woreda*, (28.44%) were from *Ankober*, (28.44%) were from Basona and (43.13%) were from *Angollela woreda*, which revealed that, the majority of one quintal (100Kg) adopters were from *Angollela woreda* as compared to the other two *woredas.* Adopters of 1-2 quintals, which include greater than one and including two quintals adopters, as shown in the Table 28, they were (147), out of which, (71.43%) were male and (28.57%) were female.

Table 28. Fertilizer adopters' distribution by the study woreda and respondents' sex

Sample HHs	Ankober	Basona	Angollela	Total	Male	Female
Total Fertilizer Adopters	136 (23.33)	210 (36.02)	237 (40.65)	583 (71.80)	441 (75.64)	142 (24.36)
Non-Adopters	134 (58.52)	62 (27.07)	33 (14.41)	229 (28.20)	163 (71.18)	66 (28.82)
Total both (Adopters & non-adopters)	270 (33.25)	272 (33.50)	270 (33.25)	812 (100)	604 (74.38)	208 (25.62)
Below one quintal adopters	52 (44.44)	36 (30.77)	29 (24.77)	117 (20.07)	90 (76.92)	27 (23.08)
One quintals adopters	60 (28.44)	60 (28.44)	91 (43.13)	211 (36.20)	168 (79.62)	43 (20.38)
1-2 quintal adopters	23 (15.64)	62 (42.18)	62 (42.18)	147 (25.21)	105 (71.43)	42 (28.57)
Above two quintals adopters	1 (1)	52 (48)	55 (51)	108 (18.52)	78 (72.22)	30 (27.78)
Total both (Adopters & non-adopters)	270 (33.25)	272 (33.50)	270 (33.25)	812 (100)	604 (74.38)	208 (25.62)
Fertilizer mean adoption (Kg)	47.41	129.485	152.13	109.72	109.387	110.70
std. dev.	57.98	113.532	121.50	111.09	110.405	113.32

Source: own computation from 2014/2015 household survey; number in parenthesis represents percent;

Concerning their distribution by *woreda*, (15.64%) were from *Ankober woreda*, (42.18%) were from *Basona woreda*, (42.18%) were from *Angollela* woreda, which revealed that the lower proportion of more than one and two quintals of fertilizer adopters were from *Ankober woreda* as compared to the other two *woredas.* Furthermore, in the study area, there were (108) adopters of more than two quintals (more than 200Kgs) fertilizer. As shown in the Table 28, out of the total (108) adopters of more than two quintals, (72.22%) were male and 30 (27.78%) were female adopters. Regarding one quintal (100Kg) of fertilizer adopters' distribution by their respective *woreda*, (1%) were from *Ankober woreda*, (48%) were from *Basona woreda,* (51%) were from *Angollela woreda*, which revealed that the higher proportion of fertilizer adopters more than two quintals were from *Angollela wereda* that followed from *Basona woreda* (48%), and the least proportion from *Ankober woreda*.

As shown in the Table 28, in most of the cases, the higher proportion of fertilizer adopters were form *Angollela woreda*, while the lower proportion were from *Ankober*, it may be due to households' resource availability to buy or take credit to buy fertilizer, and proximity to market and credit centers, the strong extension support. However, in *Ankober woreda*, due to undulating land scape, low fertility due to high erosion problem, low resource availability at farm household level, distance from credit and market center, which may limit the households to use less quantity of fertilizer than the other two study *woredas*.

Furthermore, in the study area, the total quantity of fertilizer adopted by sample households was 891 quintals, which was (8910Kgs). However, the distribution among adopters as indicated in the Table 28, showed variations. As a result, out of the total (583) total adopters, (20%) were below one quintal adopters, (36%) were one quintal adopters, (25%) were above one and two quintals adopters, and closer to (19%) were adopters of above two quintals fertilizer. On average, among the total (812) sample households, 110Kg fertilizer was adopted, and among the actual (583) fertilizer adopters, on average closer to 153 Kgs fertilizer was adopted. In this study, the focus group discussions in all the three study *woredas* (*Ankober, Basona* and *Angollela*) were conducted. The focus group discussion participants in each *woreda* were (12). Participants were selected based on their experience in barley farming and in barley technologies adoption including fertilizer.

During the discussion, the issues raised and discussed related to fertilizer were, the poor quality, high cost, high credit interest rate that limit farmers to buy and use fertilizer, and forced adoption of fertilizer were among the most important ones. Accordingly, participants confirmed that, although, it is known that fertilizer can increase crop yield, currently the serious problems on fertilizer such as poor quality, high cost, forced adoption and high interest rate of credit service to buy it, become serious from time to time. Now, the problems become closer beyond the capacity and tolerance of the farmers, which all need to be alleviated by the concerning body. The participants compare the fertilizer quality during the imperial and Derg regime by one side and the fertilizer quality during the current government (EPDRF). The current fertilizer is full of dust. But, there was no dust in fertilizer distributed during the imperial and Derg regime. The indictor for poor quality and dusty of the currently distributed fertilizer is, that when farmers sowed fertilizer, their hands become full of dust (poor quality indicator), but in the previous time fertilizer, farmers' hand after sowing became oily (high quality indicator, in addition to high yield).

The high cost of fertilizer, although, there is poor quality in the current fertilizer, some benefits from its application though yield increment is obtained. However, most of its benefits also taken by its high price and high interest rate of credit taken to buy fertilizer. Therefore, those institutions involved in fertilizer distribution, take the benefits from fertilizer to them than it should go to the farmers. Therefore, farmers adopt fertilizer to benefit credit and fertilizer providers more than themselves. That is why, they use the government power to influence farmers to buy or take in credit fertilizer. Participants said that once, they buy, they also forced to return the credit during the harvest time, which is the time of low price of agricultural products. Therefore, they forced to return by selling most of their harvest or by selling their assets such as oxen, cows, mule, etc., which thin their assets through time. Therefore, participants call this situation, credit in general, fertilizer credit in particular as *"Amenmim",* which mean in Amharic is thinning of households' assets that lead them to remain with few or without assets that again lead them serious vulnerability in food security, income constraints and finally to serious poverty as summarized in Annex 5.

Participants appreciated the importance of compost, mostly prepared form livestock manure. According to the participants, in all the three study *woreda*, except the scarcity, compost is important in improving barley production. Compost help to increase the soil mass, to lose the soil, create comfortable environment for small organisms that facilitate to loosen the soil. Once compost is added on the soil, it serves to increase yield at least for three years. But, in the case of fertilizer, the farm land needs to apply fertilizer in every year, otherwise the soil become hard, and create inconvenience environment for crops roots, as a result, the yield will decrease. Livestock manure, in the study area, *Semen Shewa* Zone (*Amhara* region), called in Amharic as *Yelijoch Gebis*, which mean barley yield increase as a result of use of manure compost, hence, food supply/availability increases. Therefore, the household who use manure compost on its barley farm land will not face food scarcity problem. In this regard, the wife and husband most of the time create conflict that the husband want to use livestock for compost on the barley farm land as fertilizer, while the wife need to use for fuel, since there is also a serious fuel wood scarcity that households use livestock manure for fuel to prepare the households' food and to warm their home. According to the focus group discussion participants, such conflict is common in all the three study *woredas* that needs solution to enhance barley production and sustainable fuel energy source for the household.

Barley in the study area is the most important cereal crop that farm households use it for food consumption and incomes source. It's by products that include straw for livestock feed and wall plastering by mixing with mud, and it's stems also used for house roof thatching, the farm households construct their houses. To improve its production, farm households use chemical fertilizer. In the study area, fertilizer is used widely in barley production. As a result, among the total (812) sample households, (71.80%) were adopted/used fertilizer in their barley production. The adopters' distribution by the respondents' sex, as shown in Table 29, out of total (583) fertilizer adopters, 75.64% were male headed households, while the rest were female headed sample households. Furthermore, among (583) adopters, 23.33% were from *Ankober*, 36.02% were from *Basona,* and 40.65% were from *Angollela woreda*, which revealed that the majority of adopters were from the two *woredas, Basona* and *Angollela,* whereas, the less adopters were from *Ankober woreda*.

Table 29. Fertilizer adoption and its contribution in farmers' income and food availability

HHs' characteristics and their fertilizer adoption		Fertilizer adopters		**Total**
		Adopters	Non-adopters	
HHs' sex	Male	441 (68.54)	163 (31.46)	604 (74.38)
	Female	142 (68.27)	66 (31.73)	208 (25.62)
	Total	**583 (71.80)**	**229 (28.20)**	**812 (100)**
Study woreds	Ankober	136 (50.37)	134(49.63)	270 (33.25)
	Basona	210 (77.20)	62(22.80)	272 (33.50)
	Angollela	237 (87.78)	33 (12.22)	270 (33.25)
	Total	**583 (71.80)**	**229 (28.20)**	**812 (100)**
HHs income status	Below (Eth. Birr 3781)	264 (63.77)	150 (36.23)	414 (51)
	Equal/above (3781)	319 (80.15)	79 (19.85)	398 (49)
	Total	**583 (71.80)**	**229 (28.20)**	**812 (100)**
HHs food availability	Below (2550 Kcal)	186 (66.43)	94 (33.57)	280 (34.48)
	Equal/Above (2550Kcal)	397 (74.62)	135 (25.38)	532 (65.52)
	Total	**583 (71.80)**	**229 (28.20)**	**812 (100)**

Source: own computation from 2014/2015 household survey data; and numbers in parentheses represent percent;

The contribution of barley in households' income and food availability, as indicated in the Table 29, out of the total (583) fertilizer adopter sample households, 54.72% were with income above and equal the minimum standard (Eth. Birr 3781) per year per adult equivalent, according to CSA and WFP (2014). In addition, fertilizer adoption also enhances the farm households' food availability, in that, out of the total (583) fertilizer adopter sample households, 68.10% were with food availability status, equal and above the minimum requirement (2550Kcal), according to CSA and WFP, 2014, which suggested that the majority of adopters, are with better food availability status (equal/above the minimum requirement) as compared to the non-adopters.

Table 30. Two sample t-test result on the contribution of fertilizer adoption on farm households' income status

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
HHs' inc	414	91.09541	5.103346	103.8377	81.06364	101.1272
HHs inco	398	155.2575	5.953441	118.7708	143.5533	166.9617
combined	812	122.5443	4.066309	115.872	114.5626	130.5261
diff		-64.16213	7.820768		-79.51349	-48.81076

diff = mean(HHs' inc) - mean(HHs inco) t = -8.2041
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 1.0000

Source: own computation from 2014/2015 household survey data

Furthermore, the two sample t-test analysis result showed that, fertilizer adopters were better in their income status. As indicated in the Table 30, on average, fertilizer adopters' income showed higher by 64.16 unit as compared to those non-adopters' income status. Similarly, the two sample t-test analysis result also showed, the importance of fertilizer adoption on the adopter farm households' food availability status improvement, in that, fertilizer adopters' food availability showed to increase significantly on average by 53.05 units as compared to the non-adopters' food availability, which suggested that as farm households adopt fertilizer, their food availability can improve through yield improvement as shown in Table 31.

Table 31. Two sample t-test result on the contribution of fertilizer adoption on farm households' food availability status

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
HHs' foo	280	87.78929	5.158152	86.31239	77.63545	97.94312
HHs' foo	532	140.8365	5.418503	124.9785	130.1921	151.4808
combined	812	122.5443	4.066309	115.872	114.5626	130.5261
diff		-53.04718	8.354929		-69.44705	-36.64732

diff = mean(HHs' foo) - mean(HHs' foo)   t = -6.3492
Ho: diff = 0   degrees of freedom = 810

Ha: diff < 0   Ha: diff != 0   Ha: diff > 0
Pr(T < t) = 0.0000   Pr(|T| > |t|) = 0.0000   Pr(T > t) = 1.0000

Source: own computation from 2014/2015 household survey data

4.6. Determinants affecting intensity of fertilizer adoption (Censored Tobit)

Adoption of agricultural technologies has influenced by interrelated components including credit, information access, risk aversion, inadequate farm size, insufficient human capital, tenure arrangements, absence of adequate farm equipment, chaotic inputs supply and inappropriate transportation and infrastructure are key constraints of adoption of innovations in less developed countries (Feder, *et. al.*, 1985). In this study, to analyze determinants affecting farm households' intensity of fertilizer adoption, censored Tobit regression model was employed; and the result of the analysis has indicated in Table 32.

According to, (Terefe and Musa, (2016), it is essential to look in to the important factors that are affecting farmers' decision to adopt organic fertilizer. Adoption of improved inputs like improved seeds, herbicide, pesticides and fertilizers increased the productivity as well as the income of adopters, which lead to increase production, to lowering the price and increasing of food access, employment creation and growth linkage effect. However, the use of agricultural technology in Ethiopia is trivial as compared to other developing countries (Mulat, 2016). The reason behind low and stagnant agricultural productivity, non-adopting and low adoption of improved technologies, such as fertilizer must be investigated (World Bank, 2012).

The predictors used in this analysis, first they were selected based on literatures, and observation of the study area. Then, description for them was given, as indicated in the Annex 1.2. section of this study. Following description, multicollinearity tests were conducted for both continuous and non-continuous explanatory variables. For continuous explanatory variables, variable inflation factor (VIF) analysis was conducted; and for non-continuous explanatory variables, correlation matrix analysis was carried out. Hence, the VIF result has summarized in Table 61 (Annex) and that of the correlation matrix result in the Table 62 (Annex). In addition, the model specification (Censored Tobit regression model) was also given in the methodology section of this study. The multicollinearity test showed that among the continuous predictors (***age, formal education in years of schooling, household size in (adult equivalent), and HH dependency ratio)*** showed multicollinearity problem. Hence they were discarded not to be included in the model (Censored Tobit Regression model) for further regression analysis. As indicated in the Table 32, the eight (8) continuous predictors that were free from serious multicollinearity problem were included in the model for further regression analysis.

Regarding the non-continuous predictors, as indicated in the Table 62, the correlation matrix analysis result that was conducted to check the existence of multicollinearity problem among the non-continuous predictors showed that all the selected thirteen (13) non-continuous predictors were free from serious multicollinearity problem. Hence, they all were included in the model (Censored Tobit regression model for further regression analysis to determine factors affecting intensity of adoption of chemical fertilizer. Therefore, those determinants affecting the intensity of fertilizer adoption were included in censored Tobit model. Then, after including predictors in Censored Tobit regression model, to see the effects of the predictors on the dependent variable, the model running was conducted. After running the model, the output, as indicated in Table 32, farm land size (positively) and market distance (negatively) and significantly affected the dependent variable (intensity of fertilizer adoption), as were hypothesized with 5% significance level, as indicated in Table 32.

Therefore, when the predictor, farm land size increase by one unit (one Ha), the probability of chemical fertilizer adoption showed to increase by 4.64% among the total (812) sample households, by 11.42 units (Kgs) among the total (812) sample households, and by 15.65 units (Kgs) among 441 uncensored sample farm households. Hence, farm land size is vital in chemical fertilizer adoption. Farm households with larger farm size can get improved technologies through different means, such as using their land as collateral. The finding in this study is in line with the findings Waithaka, *et. al.*, (2007), Tesfaye, *et al.*, (2001), Mesfin (2005), Idrisa, *et.al*, (2012); Matsumoto and Yamano (2010); Onyenweaku, *et. al.*, 2013; Negera and Getachew (2014); but different from the findings of Zhou, *et al.*, (2010).

On the other hand, credit center distance (Km) affected intensity of adoption of fertilizer. It is because when the credit center is far, it is difficult for the farm households' to easily access credit and use to buy improved technologies to enhance their agricultural production, thereby, to improve their income and food supply/availability from their production. As a result, credit center distance affected fertilizer adoption negatively and significantly as indicated in Table 25. When credit center distance increase by one unit (one Km), the intensity chemical fertilizer adoption decrease by 0.37% probability level among Total (812) sample households, by (0.91) units (Kgs) among total (812) sample households and by (1.25) units (Kgs) among (441) uncensored sample households.

In this study, the predictor, farm households' participation in *Belg* (small rainy) season production affected fertilizer adoption negatively significantly, which is differently what was presumed. Therefore, participation in *Belg* production affect the dependent variable (intensity of fertilizer adoption) to decrease. As a result, when the farm households participated in *Belg* production, their intensity of fertilizer adoption decreased by 4% probability level among the total (812) sample households, by 4 units (4Kgs) among the total (812) sample households, by 9.5 units (Kgs) among the total (812) sample households, by 13 units (Kgs) among the uncensored (441) sample households. It could be because, the rainfall during *Belg* season, and since there is no adequate rainfall, fertilizer may affect the crop growth negatively, and as a result, farmers may refuse to adopt/use fertilizer during *Belg* season.

The predictors, household food availability status, income status, credit access, extension service access, participation in barley selling options, and households' participation in improved livestock production affected the dependent variable, intensity of fertilizer adoption, positively and significantly, as were hypothesized. The significant effects of the predictors on the dependent variable were to increase (if positive) or to decrease (if negative) by some points as indicated in Table.

Table 32. Fertilizer adoption determinants analysis output using Censored Tobit Model (Kg)

Explanatory variables	Coef.	Std. Err.	P>t	Probability of change	Change among (812)	Change among uncensored (441)
				dy/dx	dy/dx	dy/dx
LIVSTOCKSIZTLU	-1.01235	1.935417	0.601	-.002412	-.5929721	-.8125124
FARMLANDHHCULT	19.49472	9.056606	0.032**	.0464479	11.41881	15.64647
MARKETDISTKM	.7224786	.5968961	0.226	.0017214	.4231834	.5798616
HHHOEDISFTCKM	.8835372	3.123045	0.777	.0021051	.5175216	.7091273
HHHOMDISDAOFKM	-1.001505	3.030809	0.741	-.0023862	-.5866198	-.8038083
CREDCENTDISTKM	-1.554284	.8791318	0.077**	-.0037032	-.9104035	-1.247469
ROADALWEDSTKM	1.021351	.7418687	0.169	.0024335	.5982442	.8197364
OXENSIZENUMB	2.777832	7.619245	0.716	.0066184	1.627083	2.229489
HHHEADSEX	-5.644614	10.62473	0.595	-.0134488	-3.306267	-4.53037
HHHMARITSTATUS	8.176462	5.731137	0.154	.0194811	4.789267	6.562431
HHFODAVLSTATUS	34.89419	10.74569	0.001***	.0831385	20.43886	28.00609
HHINCOMESTATUS	52.07103	10.33189	0.000***	.1240638	30.5	41.79223
HHFORMCREDACES	28.29305	10.82812	0.009***	.0674107	16.57232	22.70802
HHACCESAGREXT	100.8671	17.98806	0.000***	.2403246	59.08169	80.95593
HHPARTBARSELOP	67.1054	9.10458	0.000***	.1598845	39.3062	53.85881
LANDRENTINPART	-2.901289	12.33111	0.814	-.0069126	-1.699396	-2.328576
LIVSHAREDINPART	14.24672	14.41156	0.323	.0339441	8.34485	11.43442
BELGCROPPROD	-16.26217	9.179768	0.077*	-.0387461	-9.525378	-13.05203
IRRGCROPPROD	2.316349	16.69873	0.890	.0055189	1.356774	1.859103
RAINFEDSUPPIRRIG	-3.565233	21.16434	0.866	-.0084945	-2.088294	-2.861458
HHPARIMPLIVPROD	19.82188	10.39281	0.057*	.0472274	11.61043	15.90905
_cons	-97.03794	24.86992	0.000			
/sigma	116.5797	4.418835	107.91			

Observation summary		Number of Observation	812
Left censored (<50Kg)	279	LR chi2(21)	225.74
Uncensored	441	Prob. > chi2	0.0000
Right censored (>300Kg)	92	Pseudo R^2	0.036
		Log likelihood	-3032.2763

Source: own computation from 2014/2015 household survey data

As a result, when the farm households' food availability status is equal and above the minimum standard (2550 Kcal), their intensity of fertilizer adoption showed to increase by 8.3% probability level among the total (812) sample households, by 20.44 units (Kgs) among the total (812) sample households, by 28 units (Kgs), among the uncensored (441) sample households, as indicated in the Table 32. Hence, households' food availability status helps farm households to increase their intensity of fertilizer adoption.in the study area.

The predictor, households' credit service access, affected the dependent variable, intensity of fertilizer adoption in (Kg), positively and significantly as was presumed, with 1% significant level. The predictor affected the dependent variable to increase in that as farm households have access to credit service, their intensity of fertilizer adoption showed to increase by 6.74% probability level among the total (812) sample households, by 16.60 units (Kg) among (812) sample households, by 22.71 units (Kg) among uncensored (441) sample households. Hence, credit service is vital in the study area to adopt fertilizer by farm households. The finding of this study is in line with the findings of Diiro and Sam (2015), Waithaka, *et. al.,* (2007), Feder *et al.* (1985), Freeman, and Omiti (2003), who have concluded that, as income increases the farm households' use of (adoption of) improved technologies has increased. On the other hand, this finding has disagreed with the finding of Martey, *et. al*, (2014).

The predictor, income status affected the dependent variable, farm households' intensity of fertilizer adoption (Kg) positively and significantly to increase by some units/Kgs. As a result, farm households with income status is equal and above the minimum status (Eth. Birr), their intensity of fertilizer adoption showed to increase by 12.41% probability level among the total (812) sample households, by 31 units (Kg) among the total (812) sample households, and by 42units (Kg) among uncensored (441) sample households as indicated in the Table 32. The finding of this study is in line with the findings of Hussain and Perera (2004), Berihun, *et. al*, (2014), Uaiene, *et. al.* (2009), Lugandu (2013), and Idrisa, *et..al*, (2012)

The predictor, farm households' access to agricultural extension service in the study area affected the dependent variable, intensity of fertilizer adoption positively and significantly at 1% significant level, as was hypothesized. The extension access affected the dependent variable to increase by some points (units). As a result, as farm households have extension access, their intensity of fertilizer adoption showed to increase by 24% probability level among the total (812) sample households, by 59 units (Kg) among the total (812) sample households, and by 81units (Kg) among the uncensored (441) sample households. This finding is in line with the findings of Jansen, *et al*., (2006); Nkonya, *et. al.,* (2008); Birungi, (2007); and Mengistu and Siegfried (2011); Idrisa, et.al, (2012).

Farm households' participation in barley selling options affected the dependent variable, intensity of fertilizer adoption positively and significantly, as presumed, with 1% significant level. As a result, when farm households participated in barley selling options, their intensity of fertilizer adoption increased by 16% probability level among (812) sample HHs, by 39 units (Kg) among (812) sample HHs, by 52 units (Kg) among (441) uncensored sample HHs as shown Table 32. The predictor, farm HHs' participation in improved livestock production affected dependent variable, intensity of fertilizer adoption (Kg), positively and significantly, as hypothesized, with 10% significant level. The predictor's effect on the dependent variable, intensity of fertilizer adoption (Kg) showed to increase by 4.72% probability level among total (812) sample households, by 12 units (kg) among total (812) sample HHs, by 16 units (Kg) among uncensored (441) sample HHs, as indicated in Table 32.

Regarding fertilizer use during small rainy season (*Belg*), the focus group discussions that were conducted in the three study *woredas (Ankober, Basona,* and *Angollela*), one focus group discussion per *woreda* showed that most of the farm households do not use fertilizer, but short time fallow, then frequently plowing the fallowed farm can give better yield than using fertilizer. However, fertilizer application is more common during the main cropping season, *kiremt/meher* season. Most of the time, due to fear of rainfall scarcity, farmers do not use fertilizer during *Belg*/small rainy season, which showed that in the Censored Tobit regression model analysis, the predictor, farm households' participation in *Belg* production showed significant and negative correlation (differently from what was presumed) with fertilizer adoption (the dependent variable).

CHAPTER FIVE: FARM HOUSEHOLDS' AGGREGATE AND BARLEY INCOME DETERMINANTS AND THEIR CONTRIBUTIONS IN ADOPTION OF BARLEY TECHNOLOGIES

5.1. Farm households' total aggregate and barley income distribution

In the study area, the highland of *Ankober*, *Basona*, and *Angollela woreda*, barley farm households have got their income from different sources such as (i) from agricultural production that include (crop production, livestock, and production, tree growing and selling), (ii) from off-farm and non-farm activities, and (iii) from other sources such as (supports, aids, gifts, etc.). In this study, the farm households' income from different sources were summed up together, and the total payment that to be covered in the year has deducted to get the total annual sample households' income. The remaining income has compared with the minimum income required for one adult person for one year, which is in (Eth. Birr. 3781), according to CSA and WFP (2014). The sample households' income from different sources has summarized in Table 33. Therefore, the respondents' total annual income is (14,829,347 Eth. Birr), and the total household size in adult equivalent is (3339).

Furthermore, based on the survey data of the current study, the total aggregate annual income of total sample households in (Eth. Birr) is 14829347.34. When it is divided by total sample households (3339 in Adult equivalent), the result in (Eth. Birr) is 4441.25 per adult equivalent, per year, which is greater than the minimum required income of the household per year per adult equivalent in (Eth. Birr) is 3781 (CSA and WFP, 2014). The total aggregate available mean income can be computed by dividing the total available aggregate income to the total sample HHs in (Adult Equivalent); or it can be obtained by multiplying the mean available aggregate income by the total HHs 3339 in (adult equivalent).

On the other hand, the minimum required annual income for the total sample HHs can be computed by multiplying the minimum income required for one adult person per year (Eth. Birr) 3781 and the total sample HHs in adult equiv. Then, the result is (Eth. Birr 3781*3339 adult equivalent = (Eth. Birr 12,624,759). Therefore, the total income difference between the total aggregate available income and the total required annual income for the total sample HH is (14,829,347.34-12,624,759) = in Eth. Birr (2,204,588. 34). Although, the available total and mean income showed higher than the total and mean required income of total sample

Households in the study area. However, at individual level, there are sample households', who are below or equal/above the available and the required mean incomes that revealed the income concentration at individual and household level is not equal.

Table 33. Respondents' aggregate and barley income distribution

Farm HHs' Income sources	HHs' aggregate income (Eth. Birr)	Income share (percent)
Total Income from different Crops including barley	7,844,203.14	53
Livestock Income	4751670	32
Trees and wood sell income	714191	4.8
Rent income (land, animals, etc.)	72553	0.5
Off-farm income	891946	6
Supports (gifts, aids and remittance) income	554784.20	3.7
Total aggregate income including barley	14829347.34	100
Total aggregate income excluding barley income	10957206.34	73.89
Total income only from barley	3872141	26.11
Total aggregate income including barley	14829347.34	100
Total income from different crops excluding barley	3972062.14	50.64
Total income only from Barley	3872141	49.36
Total income from different crops including barley	7844203.14	100

Sample HHs' distribution		Sample HHs' aggregate and barley income (Eth. Birr)			
		Aggregate mean	St. dev.	Barley mean	St. dev.
By barley technologies adoption	Adopters (738)	18362.1336	14052.7340	4884.88	4392.39
	Non-Adopters (74)	11962.0854	8096.98603	3609.46	2339.85
Mean income difference		6400.0482		1275.42	
By study woredas	Ankober	12415.5146	8714.03305	3618.51	2563.02
	Basona	20725.0333	16245.5718	5660.22	5896.91
	Angollela	20174.2625	13559.4428	5020.60	3309.79
By sample HHs' sex	Male	18870.7892	14408.942	4953.75	3752.80
	Female	14608.1357	11006.8906	4231.14	5452.88
Mean income difference		4262.654		722.605	
Total mean income (Eth. Birr)		17778.8779	13738.9386	4768.65	4261.50

rce: own computation from 2014/2015 households' survey

As a result, when the farm households are below the minimum required income (Eth. Birr, 3781), according to CSA and WFP (2014), they considered as HHs with income below the minimum standard, represented by (0); but if their income is equal/above the minimum requirement, they considered as HHs with better income status, represented by one (1).

In this study, the sample households' total aggregate income from different sources has summarized in the Table 33. As a result, out of (14829347.34 Eth. Birr) total aggregate available annual income, the share of total income from different crop production covered

53%, from livestock 32%, off-farm income covered 6%, income from wood and tree sales 4.8%, income from supports and gifts covered 3.7% and income from (land, animal, etc., rents) covered 0.5% as indicated in the Table 33. Out of the total aggregate income of the sample households (Eth. Birr 14829347.34), income from crop (Eth. Birr 7844203.14), which was 53% as mentioned above. The total crop income of the sample households also includes income from barley, which was (Eth. Birr 3872141. The share of barley income in total crop income was (49.36%), and in total aggregate income (26.11%) as shown in the Table 33, which revealed that the share of barley income in total and in crop income was significant.

The total aggregate and mean income distribution of sample farm households has summarized by adopter and non-adopter respondents, by the study *woreda*, and by male and female respondents as indicated in the Table 33. As a result, the total aggregate mean income of adopters and non-adopters in (Eth. Birr) are (18362.134) and (11962.09), respectively. The difference between the aggregate mean income of adopters and non-adopters was (Eth. Birr. 6400.0482), which showed that, adopters are better in mean income as compared to non-adopters. Therefore, adoption of improved technologies in agriculture, in general and in barley production in particular, is very important in improving farm households' production, thereby, their income and food availability. In addition, the mean income distribution from barley among adopters and non-adopters as summarized as indicated in the Table 33, the adopters and non-adopters mean income form barley were (Eth. Birr 4884.88) and (Eth. Birr 3609.46), respectively. The mean barley income difference between adopters and non-adopters was (Eth. Birr 1275.42), which revealed that adopters are better in mean income from barely than non-adopters. Therefore, using improved barley technologies is vital in improving the income of the farm household from barley, then, it increases the total income of the farm households and their food availability and wellbeing.

Regarding the total aggregate and barley mean incomes distributions by the study *woreda*, as shown in the Table 33 were in Eth. Birr (12415.5146), (20174.2625) and (20725.0333) in *Ankober, Angollela* and in *Basona woreda* respectively. Therefore, *Basona woreda* is better in aggregate mean income than other two *woredas;* and *Ankober woreda* is the lowest in total aggregate mean income as compared to the other two *woredas.* Regarding the barley mean income distribution, in (Eth. Birr), the mean barley income in *Ankober* is 3618.5; in *Basona* 5020.60; and in *Angollela* 5660.22. Among which, *Ankober woreda* is the lowest, while

Basona woreda is better in barley mean income. Therefore, *Bsona woreda* was better both in aggregate and in barley mean income as indicated in the Table 33.

In addition, the aggregate and barley mean incomes has summarized by male and female respondents as shown in Table 33 in Eth. Birr. As a result, the male and female respondents' aggregate mean income were (18870.7892), (14608.1357), respectively, with aggregate mean income difference (4262.654) in (Eth. Birr), which revealed that the male headed respondents were better in aggregate mean income than female household respondents. Furthermore, the male and female respondents' barley mean income in (Eth. Birr), as summarized in Table 33 were (4953.75) and (4231.14), respectively with barley mean income difference in Eth. Birr (722.605). The mean aggregate income and the income from barley at *woreda* level is (3618.51) Eth. Birr in *Ankober*, (5660.22) in *Basona* and (5020.60) in *Angollela woreda*; and the *woreda* distribution of the mean income from barley is that (3618.51) Eth. Birr in *Ankober*, (5660.22) in *Basona*, and (5020.60) in *Angollela woreda*. Regarding respondent farm households' mean annual aggregate food availability and annual food availability from barley in (Kcal) are summarized in Table 33. As a result, the respondents' mean aggregate food availability is (5818097.43) Kcal, with std. dev. (4198682.18).

The *woreda* distribution and the mean aggregate food availability was (5421041.3) Kcal in *Ankober woreda*, (5576329.1) in *Bsona woreda*, and (6458712.1) in *Angollela woreda*, which revealed that the higher mean aggregate food availability is observed in *Angollela woreda* than the other two *woredas.* Concerning the respondents' mean food availability from barley is (2613388.60) Kcal, with (2463663.18) std. dev. The mean food availability from barley, its distribution at woreda level was that (2123484.34) Kcal in *Ankober woreda*, (2626152.20) in *Basona,* and (3090434.72) in *Angollela woreda*. Among which, the larger mean food availability from barley was observed in *Angollela woreda*, as shown in the Table 33.

5.2. Farm households aggregate income status and its distribution

The total respondents in the current study were (812), among which, male were (604) and female respondents (208). Out of total respondents, adopters were 738 (%) and 74 (%) non-adopters. Furthermore, the total (812) sample households' distribution by the study *woreda (Ankober, Basona* and *Angollela)* has summarized in the Table 35. As a result, (33.25%) were from *Ankober*, (33.50%) from *Basona* and (33.25%) were from *Angollela woreda*. Regarding the male and female sample households' distribution, as indicated in the Table 34, (74.38%) were male and (25.62%) were female. Furthermore, the sample households' distribution based on their annual aggregate income status, (51%) were below minimum, which is (Eth. Birr 3781), according to CSA and WFP (2014).

Furthermore, the male and female sample households' distribution by their income status can be grouped. As a result, the male sample households were (604) and the female were (208). Among the male respondents (604), those with income below the minimum standard were (52.15%), and those with income status equal/above the minimum standard were (47.85%), which revealed that the larger proportion of male respondents were below the minimum income status. Regarding the female respondents, out of (208) female respondents, (47.60%) were below the minimum income status, while (52.40%) were equal and above the minimum income status, which revealed that the larger proportion of female respondents were with better income status as compared to the male respondents.

Table 34. Barley technologies adopters and non-adopters' distribution by income status

Sample HHs distribution		Sample HHs distribution by total income status (Eth. Birr)		**Total**
		Below (3781 Eth. Birr)	Equal and above (3781 Eth. Birr)	
By adoption of barley technologies and income status	Non-Adopters	52 (70.27)	22 (29.73)	74 (9.11)
	Adopters	362 (49.05)	376 (50.9)	738 (90.89)
By study woredas and income status	Ankober	206 (76.30)	64 (23.70)	270 (33.25)
	Basona	103(37.87)	169 (62.13)	272 (33.50)
	Angollela	105 (38.89)	165 (61.11)	270 (33.25)
By HHs' sex and income status	Male	315 (52.15)	289 (47.85)	604 (74.38)
	Female	99 (47.60)	109 (52.40)	208 (25.62)
Total sample HHs distribution by their income status		414 (51%)	398 (49%)	812 (100%)

Source: own organization from household survey (2014/2015); and numbers in parentheses represent percent;

On the other hand, based on income status, sample households are classified in to male and female households. As a result, out of the total (414) sample households with income below the minimum status, 315 (76.09%) were males and the rest 99 (23.9%) were females. Regarding, those (398) sample households with income equal and above the minimum income standard, 289 (72. 61%) were male and the rest, 109 (27.39%) were female respondents. Among the male respondents 315 (52.15%) were with income below the minimum standard; while the rest 289 (47.15%) were with income below the minimum (Eth. Birr 3781) income standard. The results showed that, a little bit larger proportion of male respondents were below the minimum income standard; while a little bit larger female respondents were with income equal/above the minimum income standard (Eth. Birr. 3781).

Respondents from each study *woreda*, as shown in Table 34, were grouped in to respondents with income status below and equal/above minimum threshold. As a result, respondents from *Ankober woreda*, were (270), out of which, (76.30%) were with income below the minimum standard (Eth. Birr. 3781), while the rest (23.70%) were with income status equal/above the minimum standard. Respondents from *Basona woreda* were (272), out of which (37.87%) were with income below the minimum standard, while the rest (62.13%) were with income equal/above the minimum standard; and respondents from *Angollela woreda* were also (270), out of which (38.89%) were with income below the minimum standard, while the rest (61.11%) were with equal/above the minimum income standard (Eth. Birr 3781). The result showed that the larger proportion of sample households in *Basona* and *Angollela woreda* were with income status equal/above the minimum income status, while the larger proportion of respondents in *Ankober woreda* were with income status below (Eth. Birr. 3781), the minimum income standard.

Regarding the *woreda* distribution of respondents, out of the total (414) sample households with income status below the minimum standard, (49.76%) were from *Ankober*, (24.88%) were from *Basona*, and (25.36%) were from *Angollela*, which revealed that among the total (414) sample households, the majority of them are from *Ankober woreda* as compared to the other two *woredas, Basona* and *Angollela woreda*. On the other hand, among (398) respondents with income status equal and above the minimum standard, (23.70%) were from *Ankober*, (62.13%) were from *Basona*, and (61.11%) were from *Angollela woreda*, which revealed that the lower size of respondents with income equal and above the minimum standard was from *Ankober woreda*; while the higher size respondents with income equal and above the minimum standard are from *Basona* and *Angollela woredas*, as indicated in the Table 34, which revealed that households from these two *woredas* are better in their income status than farm households in *Ankober woreda*.

Sample households, based on their barley technologies adoption as indicated in Table 35, were subdivided in to below and equal/above minimum income status. In this study, farm households use/adopt different barley technologies in their barley production that include adoption of barley farm land frequent plow, Fertilizer, Manure compost, Frequent hand weeding, Weedicide, Barley farm land drainage practices, Improved barley seed, and improved farm tools. As a result, as indicated in Table 35, out of the aforementioned barley technologies, based on adopters' size, the first ranked adopted technology was barley farm land frequent plow (3 times or more), which was adopted by 600 sample farm households. The income distribution of these (600) adopters as indicated in Table 35, 47.83% were with income below the minimum standard; while the rest 52.17% were with equal/above minimum income standard, which revealed that a little bit larger than half of the sample households were with better in their income status.

Table 35. The roles of barley technologies adoption on farm HHs' total income status

Barley technologies adopted by farm HHs	Sample HHs income status by adoption		Adopters, Non-adopters and Adoption rank of the technology based on adopters' number		
	Below (3781) Eth. Birr	Equal/above (3781)Eth. Birr	Adopters	Non-adopters	Rank based on adopters' number
Barley farm land frequent plow	287 (47.83)	313 (52.17)	600 (73.90)	212 (26.10)	1st
Fertilizer adoption	264 (45.28)	319 (54.72)	583 (71.80)	229 (28.20)	2nd
Manure compost	203 (44.81)	250 (55.19)	453 (55.80)	359 (44.20)	3rd
Frequent hand weeding of barley	185 (48.43)	197 (51.57)	382 (47.04)	430 (52.96)	4th
Weedicide	161(46.94)	182 (53.06)	343 (42.24)	469 (57.76)	5th
Barley farm land drainage	98 (43.95)	125 (56.05)	223 (27.46)	589 (72.54)	6th
Improved barley seed adoption	70 (43.75)	90 (56.25)	160 (19.70)	652 (80.30)	7th
Use of improved farm tools	63 (41.45)	89 (58.55)	152 (18.72)	660 (81. 28)	8th
Total sample HHs	414 (51)	398 (49)	738 (90.89)	74 (9.11)	812

Source: own organization from household survey (2014/2015);and numbers in parentheses represent percent;

Following the frequent plow practice, the second ranked barley technology, which was adopted by (583) sample households was chemical fertilizer. Out of these adopters of chemical fertilizer, (45.28%) were below the minimum income status, while the rest (54.72%) were with equal/above the minimum income standard. The third ranked barley technology, adopted by (453) was manure compost. Out of which, (44.81%) were with income below the minimum standard, while the rest (55.19%) were with equal/above minimum income status.

The fourth ranked barley technology adopted by (382) was frequent hand weeding of barley crop. Out of which (48.43%) were with income status below the minimum standard, while the rest (51.57%) were with income equal/above the minimum standard (Eth. Birr 3781). Based on the number of adopters of the technology, the fifth ranked barley technology was weedicide chemical, adopted by (343) sample farm households. Out of which, (46.94%) were below the minimum income standard; while the rest (53.06%) were with income equal and above the minimum income status, as shown in Table 35. The sixth ranked barley technology, adopted by (223) sample farm households was barley farm land drainage practices. Out of which, (43.95%) sample household adopters were with income status below minimum standard, while (56.05%) were with equal/above minimum income status.

The seventh ranked barley technology adopted by (160) sample households was improved barley seed. Out of these adopters, (43.75%) were with income below the minimum standard, while the rest (56.25%) were with equal/above the minimum standard. The eighth ranked barley technology adopted by (152) sample households was improved farm tools, which include (BBM/Broad Bed Molder and small scale irrigation pumps. Out of these 152 adopters, (41.45%) were with income status below the minimum standard, while the rest (58.55%) were with equal/above the minimum standard. As it is observed in Table 35, among the adopters of each of the aforementioned barley technologies, the majority of adopters are with income equal/above the minimum required income standard (Eth. Birr 3781), which revealed that adoption of improved technologies in the study area are vital for the adopter farm households' to enhance their income and wellbeing.

Furthermore, adoption of barley technologies farm households' income status showed the strong association as the chi-square test result showed in Table 36. The chi-square test results showed that adoption of frequent plow (three or more times plowing) associated with income status of adopters significantly at 1% significant level. The association of fertilizer adoption and adopters' income status showed significant association with 1% significance level. Compost/manure adoption also showed significance association at 1% significance level.

Table 36. Farmer' income status and its association with improved barley technologies

Barley technologies adoption status		HHs' income status (below or equal/above (3781Eth. Birr) per year per adult. eqv.		Chi-square test result	
		Below	Equal/above	X^2 -Value	Sign.
Frequent plow (3≤)	Adopters (600)	287	313	9.136	.002
	Non-adopters (212)	127	85		
Fertilizer	Adopters (583)	264	319	27	.000
	Non-adopters (229)	150	79		
Compost/manure	Adopters (453)	203	250	15.623	.000
	Non-adopters (359)	211	148		
Frequent weeding (2≤)	Adopters (382)	185	197	1.886	.096
	Non-adopters (430)	229	201		
Weedicide	Adopters (343)	161	182	3.891	.029
	Non-adopters (469)	253	216		
Farm land drainage	Adopters (223)	98	125	6.095	.008
	Non-adopters (589)	316	273		
Improved barley seed	Adopters (160)	70	90	4.174	.025
	Non-adopters (652)	344	308		
Total barley technologies	Adopters (738)	362	376	12.117	.000
	Non-adopters (74)	52	22		

Source: own computation from 2014/2015 HH survey data

*The chi-square test analysis result showed that different barley technologies adoption and income statuses of farm HHs in the study area showed significant association.

Weedicide adoption, frequent hand weeding (2 and more times weeding), Improved barley seed adoption and Farm land drainage practices adoption showed significant association with adopters' income status at 5%, 1% and 5% significant level, respectively; and the overall barley technologies adoption showed significant association with sample farm households' income status at 1% significant level, as indicated in Table 36.

5.3. Farm households' aggregate income status determinants

Analyses of determinants affecting the aggregate and income from barley were conducted using inferential statistics. In the study area, the different income sources of farm households include (agriculture, off-farm, credit, gift/aids, remittances, etc.,). In this study, the farm households aggregate income was conceptualized as the total aggregate income available for households' consumption, after deducting all the costs that need to be covered/paid during the survey year. Then, the remaining available income for household's consumption/expenditure was divided by total sample households based on the adult equivalent requirement. As a result, if the income of the household (at household level) become below the minimum standard, 3781 (Eth. Birr), which is according to CSA and WFP (2014), the household was considered as the household with income below the minimum income standard, which was represented by zero (0); but, when the farm households' income is equal and above the minimum standard, the household was considered as the household with income equal and above the minimum income standard and was represented by (1).

Based on the minimum required income standard (Eth. Birr 3781) determined by CSA and WFP, (2014), out of the total (812) sample households (51%) were below and the rest (49%) were with equal/above minimum required income status. After determining the sample farm HHs' income status, which is the dependent variable, description and checking of the selected predictors for the problem of multicollinearity problem both for the continuous and non-continuous predictors were conducted. For continuous predictors variable inflation factors analysis, and for the non-continuous predictors, correlation matrix analysis was conducted and the results of the tests have been presented in Table 63 (Annex) for correlation matrix result and in Table 64 (Annex) for (VIF) test result.

After checking the multicollinearity problem, the explanatory variables were included in the Logit regression model to identify determinants affecting the farm households' income status, based on their aggregate income amount. After including the predictors and running the Logit model, to identify the farm households' income status determinants, the regression output has shown in the Table 37. As the regression model output has shown in Table 37, out of the total 20 explanatory variables included in the Logit regression model, ten (10) were significant, while the rest nine (9) were insignificant in affecting the sample farm households' aggregate income status. The ten (10) significant predictors include (household size, Livestock size, market distance, household food availability, household head sex, fertilizer adoption, credit access, off-farm participation, participation in barley selling options, and participation in improved livestock production), as shown in Table 37.

Table 37. Binary Logit output on farmers' aggregate income status determinants (Eth. Birr)

Predictors	Coef.	Std. Err.	z	P>|z|	dy/dx (marginal effect)
AGEHHHEAD	-.0011302	.0073783	-0.15	0.878	-.0002821
HHHFORMEDUYR	.0450072	.0411085	1.09	0.274	.0112334
HHSIZEADEQV	-1.036766	.0941549	-11.01	0.000***	-.2587665
LIVSTOCKSIZTLU	.1658256	.034368	4.82	0.000***	.0413884
FARMLADCULT	.0663437	.2045196	0.32	0.746	.0165587
MARKDISTKM	-.0301186	.0147744	-2.04	0.041**	-.0075173
AVAFODPRODKC	4.16e-07	4.44e-08	9.37	0.000***	1.04e-07
HHHEADSEX	-.4955488	.2296358	-2.16	0.031**	-.1220289
ADOPFERTBARL	.4977674	.2382381	2.09	0.037**	.1237804
ADOPCOMPBARL	.113694	.2110868	0.54	0.590	.0283766
ADOPWEEDCIDE	.1425326	.2202348	0.65	0.518	.0355428
ADOPFREQPLOW	.2131304	.2784922	0.77	0.444	.0532202
ADOPFRQWEDING	-.2353277	.2388881	-0.99	0.325	-.0586839
ADOPIMPBARSEED	-.3088533	.2919113	-1.06	0.290	-.0770572
ADOPFRMDRNAGE	.0735257	.2470998	0.30	0.766	.0183357
FORMCREDACES	.739769	.2559609	2.89	0.004***	.179294
HHOFFARMPART	1.172464	.2381115	4.92	0.000***	.2776434
BARSELOPTNS	.3741502	.1377797	2.72	0.007***	.0933842
PARIMPLIVSPROD	.6643122	.2296836	2.89	0.004***	.1658058
ACESBARLEXT	-.2454547	.2377852	-1.03	0.302	-.0609449
_cons	.1332518	.5030427	0.26	0.791	

Logistic regression	Number of obs	=	812
	LR chi2(20)	=	455.79
	Prob > chi2	=	0.0000
Log likelihood = -334.78344	Pseudo R2	=	0.4050

Source: own computation from 2014/2015 HH survey data
*, **, ***, which show significance level at (10%, 5%, and 1%) respectively;

Among the significant predictors (household size, market distance and household head sex) showed negative significance in affecting the dependent variable (farm households' aggregate income status); while the rest that include (livestock size, available food, fertilizer adoption, access to formal credit, off-farm participation, participation in barley selling options, and participation in improved livestock production) showed positive significance in affecting the dependent variable (farm households' aggregate income status).

The logistic regression model analysis output regarding the predictors affecting the dependent variable, as indicated in the Table 37, the negative effect of the household size in adult equivalent is as was presumed in affecting the dependent variable negatively and significantly (which is at 1%) significant level. As the model output showed that, when the sample farm household size has increased by one unit (in adult equivalent), the aggregate income status of the farm households has shifted from the income status with equal and above the minimum status to the below minimum income status by 26 % probability level, which revealed that the higher the household size, the higher could be the consumption of the household, which leads to decrease the income status of the household. This finding of this study is in line with the findings of Saranian (2015), Talukder (2014), Ademiluyi (2014), Adekoya (2014), Asogwa, *et. al,* (2012), Ukoha, *et. al,* (2007), Hassan and Babu (1991), Okurut, *et. al*. (2002), Gang, *et.al.* (2002), Bokosi (2006), Anyanwu (2010);Masood and Nasir lqbal (2010), World Bank (1996), FOS (1999), Omonona (2001).

The predictor, market distance (Km) and the dependent variable farm household's aggregate income status was correlated negatively and significantly as was presumed. The negative and significant effect of market distance on the sample farm households' aggregate income status is at 5% significant level. The effect of the predictor on the dependent variable, as indicated in the Table 37, when market distance increases by one unit (1Km), the dependent variable, farm households' aggregate income status was shifted from the income status of equal/above status to the income status below (Eth. Birr 3781) the minimum standard, according to CSA and WFP (2014). The significance level of the effect of market distance on the dependent variable is at 5% significant level. As the model output showed that, when the market distance increases by one unit (1Km), the income status of the farm household was shifted from the income status of equal and above the minimum standard to the income status below the minimum standard with the probability (0.75%), which revealed that as farm households are far from the market center, they miss many opportunities, such as information, improved innovations, linkages and network, etc., that can help them to enhance their income status. This finding is consistence with the finding of Shiferaw, *et. al.*, (2003).

The predictor, household head sex correlated with the dependent variable household income status, negatively and significantly; and differently from what was hypothesized with 5% significance level. As indicated in the Table 37, the income status of farm households headed by male showed to decrease in income status by 12.20% probability level as compared to the income status of households headed by female, which revealed that, in this study the female headed households showed better in their income status than male headed households. The possible justification might be that female household heads may give more care, attention to their family and they save better than male (who are most of the time extravagant in spending the households' income), better in investing, in income generating and enhancing activities than male head households. However, this finding of this study is inconsistence with the findings of Fadipe, *et. al.*, (2014), Su and Heshmati (2013), Lhing, *et. al*, (2013).

The logistic regression model analysis output regarding the effects of positive and significant predictors in affecting the dependent variable (aggregate farm household's income status), the model results have summarized in Table 37. As a result, the predictor livestock size in (TLU) affected the dependent variable as was presumed positively and significantly, with (1%) significant level. As the model result showed that, when the farm household's livestock ownership has increased by one unit (one TLU), the income status of the farm households showed to shift from the below minimum income status to equal/above minimum income status with 4.14% probability level. This finding is in line with the findings of Zhang, *et.al.*, (2012), Hossein (1988), Demissie (2003), Fikru (2008), FOS (1999), Omonona (2001), Ademiluyi (2014), Sallawu, *et. al*, (2016).

The predictor, households' food availability in (Kcal) and the households' aggregate income status (the dependent variable), showed the positive and significant correlation as was hypothesized, with 1% significant level. The effect of the predictor on the dependent variable showed that, when the farm households' food availability has increased by one unit (1Kcal), the sample farm household's income status showed to shift from the below level of income status to the level with income equal/above minimum standard by 0.4% probability level, which revealed that, when the farm households are better in food availability status, they might motivate to involve in different income generating activities. This finding is in line with the finding of Adane (2003); and Cuddy, *et. al.*, (2008). Fertilizer adoption also affected the dependent variable, farm households' aggregate income status positively and significantly as was presumed, with 1% significant level. The positive and significant effect of fertilizer adoption on the dependent variable showed to shift the income status of farm households from the below status to equal/above the minimum income status with the probability level of 12.40%. Therefore, adoption of fertilizer is crucial to improve the farm households' income status. This finding is in line with the finding of Berihun (2014), who concluded that fertilizer use was found to affect adopters' income positively and significantly.

The predictor, farm households' access to credit and the dependent variable showed also the positive and significant correlation as was presumed, at 1% significant level as indicated in the Table 37. The result of the model analysis showed that, as the farm households' access to formal credit service, their income status showed to shift from the below minimum income status to the level of equal/above minimum income status, with the probability level of 18%, which revealed the importance and role of credit to enhance farm households' income status. This finding is in line with the finding of Adetayo (2014), Adeyeye (2001). However, the findings of Agwu and Orji (2013), Asogwa, *et. al.,* (2012), FOS (1999), and Omonona (2001) are inconsistence with the finding of the current study. The predictor, off-farm participation and farm households' income status showed the positive and significant correlation as was presumed, with 1% probability level. In this regard, when the farm households were participated in off-farm activities their income status showed to shift from the lower level (HHs' income status below the minimum status) to the income status equal and above the minimum income status with the probability level of 28%. This result has suggested that, off-farm plays an important role in improving the farm households' income status. This result is in line with the finding of Farm Business Unit, (2013), that many farming households derive some proportion of income from off-farm sources.

The predictor, participation in barley output selling options and farm household's income status showed positive and significant correlation as was hypothesized, with 1% probability level. The positive effect of the predictor is that when farm households participated in off-farm activities, their income status showed to shift from the below income status to equal/above the minimum standard with the probability of 9.34%. This finding is in line with the findings of Asogwa, *et. al.,* (2012) and (Tchale, 2009). The predictor, farm households' participation in improved livestock production and the dependent variable, farm households' aggregate income status also showed positive and significant correlation as was presumed, with 1% significant level. The predictor affected the dependent variable in that, as farm households' participated in improved livestock production, their income status showed to shift from below minimum required income status to equal/above income status with the probability 17%. This finding is in line with the finding of Kabunga (2014).

5.4. Farmers' aggregate income determinants (multi-linear regression model)

To identify determinants affecting the total aggregate income intensity of sample farm households in the study area, multiple-linear regression model was employed; and the output of the analysis has summarized in Table 39. However, before running the multi-linear regression model by including the predictors, first, the test for the existence of multicollinearity problem was conducted both for continuous and non-continuous predictors. Therefore, for the continuous predictors, Variable Inflation Factor (VIF) analysis was carried out, and for non-continuous explanatory variables, correlation matrix analysis was conducted; and the results of both tests are indicated in the Table 65 (Annex) for the VIF result, and in the Table 66 (Annex) for the correlation matrix result. As shown in the Table 66 (Annex), among the continuous predictors, market distance (km) showed multicollinearity problem. Hence, it was discarded not to be included in the model and not to be used in the further analysis of multiple linear regression model. Furthermore, the correlation matrix analysis was conducted to test the existence of multicollinearity problem and the test result has shown in Table 67 (Annex) that there is no serious multicollinearity problem, all the non-continuous explanatory variables were included multiple linear regression model for further analysis.

Therefore, in this analysis, to determine factors affecting farm households' aggregate income intensity in Eth. Birr, twenty (20) predictors, which include both (continuous and non-continuous) predictors were included in the multiple linear regression model for further analyses. The result of the model has summarized in the Table 38 that showed, out of the twenty (20) predictors, which were free from multicollinearity problem, five continuous (5) and eight (8) non-continuous predictors, a total of thirteen (13) predictors were affecting the dependent variable significantly. The continuous and significant predictors with their coefficient signs that were included in the multiple linear regression model include the household head formal education in years of schooling (+), household size in adult equiv. (-), livestock size in TLU (+), farm land size (+), and households' food availability (+).

The non-continuous significant predictors include fertilizer adoption (-), compost adoption (+), weedicide adoption (+), improved seed adoption (-), households' off-farm participation (+), barley selling options participation (+), land rent–in participation (+), and participation in improved livestock production (+). Three predictors showed negative sign in their coefficient, which means, they affected the dependent variable significantly to reduce in some units as indicated in Table 38. The negative significant predictors, as indicated in Table 38 were household size in adult equivalent at 5% significant level, adoption of fertilizer at 10% significant level and adoption of improved barley seed at 5% significant level were affect the dependent variable, the households' aggregate income intensity measured in Eth. Birr, negatively and significantly with different significance level as indicated in Table 38. Among which, the negative effect of household size is as was hypothesized; but the effects of fertilizer and improved barley seed were different from what were hypothesized. As a result, when the sample farm household size increase by one unit (one adult equivalent), the aggregate intensity of income showed to decrease by 511 Eth. Birr. This finding is inconsistency with the finding of Berihun (2014) that family size and income of the household showed positive and significant correlation.

Regarding farm households' adoption of fertilizer in this study, when the farm households' fertilizer adoption increased by one unit (1kg), their aggregate intensity of income decreased by 1444.42 Eth. Birr, which also inconsistent with the finding of Berihun (2014) that concluded, fertilizer adoption helps to increase households' income. Adoption of improved barley seed in this study showed negative correlation with farm households' income intensity, which is different from what was presumed. The negative effect of farm households' adoption of improved barley seed has shown that, when the farm households' adoption of improved barley seed increased by one unit (1kg), the intensity of farm households' income decreased by 2284 Eth. Birr. The finding of this study is inconsistence with the finding of Shiferaw, *et. al.*, (2003) and Ahmed (2015), who concluded that improved seed users were better in their food security status (proxy variable for income) than non-users.

Farm households' formal education in years of schooling in this study showed the positive effect on the dependent variable (the farm household' intensity of income in Eth. Birr), which is as was presumed, with 10% significant level. The effect of formal education on the dependent variable as shown in the Table 35 was that, when the sample farm household's formal education in year of schooling increased by one year, the intensity of farm household's aggregate income showed to increase by 247.40 Eth. Birr, which is in line with the finding of (Fadipe, *et. al.*, 2014).

Table 38. Farm households' aggregate income intensity (Eth. Birr) determinants (Multiple linear regression model analysis output)

Predictors	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LOGAGEYR	-688.0583	3119.351	-0.22	0.825	-6811.243	5435.126
HHHFORMEDUYR	247.3715	150.6946	1.64	0.100*	-48.43705	543.1801
HHSIZEADEQV	-510.9667	228.6564	-2.23	0.026**	-959.8117	-62.12174
LIVSTOCKSIZTLU	767.1425	107.0745	7.16	0.000***	556.9586	977.3264
FARMLADCULT	3397.098	718.8229	4.73	0.000***	1986.072	4808.124
HHFOODAVLOG	8482.295	637.175	13.31	0.000***	7231.541	9733.049
HHHEADSEX	-77.55574	812.0981	-0.10	0.924	-1671.678	1516.567
ADOPFERTBARL	-1444.418	844.1741	-1.71	0.087*	-3101.505	212.668
ADOPCOMPBARL	1275.007	750.1681	1.70	0.090*	-197.5491	2747.562
ADOPWEEDCIDE	1404.274	770.3668	1.82	0.069*	-107.9313	2916.479
ADOPFREQPLOW	1231.434	990.3559	1.24	0.214	-712.6028	3175.47
ADOPFRQWEDING	-279.475	834.9516	-0.33	0.738	-1918.458	1359.508
ADOPIMPBARSEED	-2284.162	969.3221	-2.36	0.019**	-4186.91	-381.4143
ADOPFRMDRNAGE	-503.6419	862.9737	-0.58	0.560	-2197.631	1190.347
FORMCREDACES	876.7064	864.3793	1.01	0.311	-820.0422	2573.455
HHOFFARMPART	5533.761	789.3966	7.01	0.000***	3984.201	7083.321
BARSELOPTNS	741.7657	412.4214	1.80	0.072*	-67.80404	1551.336
LANDRENTINPART	2743.454	939.6461	2.92	0.004*	898.9588	4587.948
HHACESBARLEXT	-870.8501	844.0591	-1.03	0.303	-2527.711	786.0105
PARIMPLIVSPROD	3170.633	809.5566	3.92	0.000***	1581.5	4759.766
_cons	-120531.7	10881.19	-11.08	0.000	-141891.1	-99172.24

Source	SS	df	MS		
				Number of obs =	812
				F(20, 791) =	43.33
Model	8.0036e+10	20	4.0018e+09	Prob > F =	0.0000
Residual	7.3047e+10	791	92347512.1	R-squared =	0.5228
				Adj R-squared =	0.5108
Total	1.5308e+11	811	188758433	Root MSE =	9609.8

Source: own computation from 2014/2015 HH survey data
*, **, ***, which show significance level at (10%, 5%, and 1%) respectively;

The farm households' livestock ownership and farm households' intensity of total aggregate income showed positive and significant correlation as was presumed, with 1% significant level. Regarding the effect of livestock size on farm household's intensity of aggregate income as shown in Table 38 was that, when the farm household's livestock ownership in TLU increase by one unity (TLU), the farm household's intensity of total aggregate income showed to increase by 767 Eth. Birr. This result has revealed that the livestock ownership has played vital role in enhancing the farm households' intensity of aggregate income. This finding has agreed with the findings of Berihun (2014) and Beyan (2016) who concluded that the livestock ownership is significantly important in enhancing farm households' income.

The predictor farm land size and the dependent variable, household's intensity of aggregate income showed positive and significant correlation as was presumed, with 1% significant level. Farm land size affected the dependent variable in that when farm land size in (Ha) increased by one unit (1 ha), the intensity of aggregate income of the household showed to increase by 3397 Eth. Birr. This finding is consistent with the findings of Olomola, (1988), Sharma, *et. al.*, (2007), Jayne, *et. al.*, (2008), Oluwatayo, *et. al.*, (2008), Ibekwe, (2010), Ghafoor, *et. al.*, (2010), Parvin1 and Akteruzzaman (2012), Drafor, *et. al*. (2013) Fadipe, *et. al*, (2014), Berihun (2014), Talukder (2014), Beyan (2016) and Karmini (2016) that, the farm land size is the most important variable affecting farm households' income both in annual gross and net income obtained from various sources.

The predictor, household's food availability (Kcal) and their aggregate income showed positive and significant correlation as was presumed. Hence, when households' aggregate food availability in (Kcal), increased by one unit (Kcal), their aggregate total annual income intensity showed to increase by 8482.30 Eth. Birr, which is in line with the finding of Kidane (2001); Degnet *et. al.* (2001); Getahun (2004), who concluded that households' food availability status and their aggregate income associated positively and significantly. The predictor, compost adoption and the dependent variable, household's aggregate income intensity, showed positive and significant correlation, as was presumed, at 10% significant level. Compost adoption affected the dependent variable, household's aggregate income intensity in that, when the household adopted compost, the aggregate income intensity showed to increase by 1275 Eth. Birr. This finding is in line with the finding of Hossain, *et. al.*, (1994) that compost adoption and income associated positively and significantly.

The weedicide adoption, it showed positive and significant correlation with the dependent variable (household's aggregate income intensity in Eth. Birr) as was hypothesized, with 10% significant level. The effect of weedicide on the dependent variable, household's intensity of aggregate income (Eth. Birr) as shown in the Table 38 that, when the farm household adopted weedicide, its aggregate income intensity in Eth. Birr showed to increase by 1404 Eth. Birr.

The predictor, sample farm household’s participation in off-farm activities to generate income and the dependent variable, household’s intensity of aggregate income showed the positive and significant correlation as was hypothesized, with 1% significant level. The predictor, household’s participation in off-farm activities affected the dependent variable, intensity of household’s aggregate income (Eth. Birr) in that, when the farm household participated in off-farm activities, their aggregate income intensity showed to increase by 5533.80 Eth. Birr. This finding has agreed with the finding of Berihun (2014) that off-farm participation of farm households has contributed an incremental role in income.

The predictor, household’s participation in barley selling options and the dependent variable, household’s intensity of aggregate income in Eth. Birr showed positive and significant correlation as was presumed, at 10% significance level. The predictor, household’s participation in barley selling options affected the dependent variable, intensity of household’s aggregate income in Eth. Birr in that, when the farm household’s participated in barley selling options, the intensity of their aggregate income showed to increase by 741.80Eth. Birr. This result is in line with the finding of Tigist (2017) that markets open opportunity to farm HHs to sell their farm outputs, and may buy and use improved inputs that helps them to remain economically self-sufficient and maintain food security.

The predictor, farm household’s participation in land rent-in practice and the dependent variable, farm household’s intensity of aggregate income showed positive and significant correlation at 1% significant level. The predictor affected the dependent variable, in that, when the farm household’s participated in farm land rent-in, their aggregate income showed to increase by 2743 Eth. Birr. Furthermore, the predictor, household’s participation in improved livestock production and the intensity of farm household’s aggregate income in Eth. Birr showed positive and significant correlation as was hypothesized at 1% significant level. The predictor, farm household’s participation in improved livestock production affected the dependent variable, intensity of farm household’s aggregate income in Eth. Birr in that, when households participated in improved livestock production, their aggregate income intensity showed to increase by 3170.63 Eth. Birr as indicated in Table 38. This result is in line with the finding of Kabunga (2014) that adoption of improved dairy cows’ decreases food and non-food poverty inequality by 4 to 7%, through improving the income and food security of households.

5.5. The contribution of barley technologies adoption on farm households' aggregate income intensity (Eth. Birr)

In the world almost the two-third poor people of the world people are living the rural areas, and most of them, for their livelihoods, depend on agriculture, according to Mogues, *et. al.* 2009). Agriculture is the engine for sustainable development in the third world countries. However, it is often constrained by access to relevant technologies and improved practices, institutional weaknesses, research, and advisory extension systems. Consequently, agrarian communities and agricultural systems in many countries operate under severe limitations and face major stumbling blocks to the use of knowledge, skills, and innovation for development. Nonetheless, smallholder productivity remains low because of poor production inputs, market, and credit, and extension services (Davis, *et. al*., 2010).

Rapid technological change that lead to productivity improvement has clearly occurred in developing world, primarily over the last half century, especially during Green Revolution. The promotion of agricultural technologies can increase household incomes. Agricultural innovation can have both direct and indirect effects on livelihood and productivity improvement of the beneficiaries. Which is more important will be determined largely by a household adopts new technologies (Adebayo and Olagunju, 2015). Gains from new agricultural technology influenced the poor directly, by raising incomes of farm households and, indirectly, by raising the employment and wage rates of functionally landless laborers, and by lowering the price of food staples (Bellon, *et. al.*, 2006; Diagne, *et al.*, 2009). It is believed the adoption of new agricultural technology, could lead to significant increases in agricultural productivity in Africa and stimulate the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy (World Bank, 2008).

Agricultural productivity gains can help reduce rural poverty by raising real income from farming and keeping food prices from increasing excessively by improving the availability of food. The economic importance of improving agricultural productivity is even more evident in a country like Ethiopia where agriculture accounts for 47% of its GDP 85% of its employment (Dorosh, 2012). Ethiopia is an agrarian country where more than 80% of the total population depends directly or indirectly on agriculture. Agriculture contributes for about half of the GDP and for more than 90% of foreign exchange earnings. Cereals (mainly teff, wheat, maize, and sorghum) are dominant in different parts of the country satisfying about 70% of the average Ethiopian's calorie intake (Howard, *et. al.*, 1995; Abebe, 2000). While agricultural productions are still taking place using traditional methods, efforts need to be made to improve situations through dissemination of improved agricultural technologies. Barley is one of the most important grain crops in Ethiopia, its productivity is low due to several factors. Of these, the major ones are poor soil fertility, use of low-yielding cultivars, poor agronomic practices, diseases and pests (Woldeyesus, *et. al.*, 2002).

In the study area *Ankober*, *Basona* and *Angollela woreda*, barley is widely produced traditionally and using different improved technologies/practices. Out of total (812) sample households' used in this study, (738) were adopters and (74) were non-adopters of improved barley technologies in their barley production. To see the contribution of barley technologies, on farm households' income, the two sample t-test analysis was conducted, and the result of the analysis has shown in the Table 39. As a result, the total aggregate annual income of the adopters is higher by (Eth. Birr 6400) than non-adopters, which revealed that adoption of barley technologies is important in enhancing farm households' income.

Table 39.Two sample t-test output on the contribution of barley technologies adoption on farm households' total aggregate income intensity in Eth. Birr

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	11962.09	941.2555	8096.986	10086.17	13838
Adopters	738	18362.13	517.2883	14052.73	17346.6	19377.67
combined	812	17778.88	482.1422	13738.94	16832.48	18725.27
diff		-6400.048	1661.161		-9660.736	-3139.36

```
    diff = mean(Non-adop) - mean(Adopters)                     t =  -3.8528
Ho: diff = 0                                  degrees of freedom =      810

    Ha: diff < 0                Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0001         Pr(|T| > |t|) = 0.0001          Pr(T > t) = 0.9999
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Source: own computation from 2014/2015 HH survey

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5.6. Determinants affecting the intensity of income from barley

Increased agriculture productivity is one of the most important options in economic growth, reducing poverty, and improving food security. Improved technologies such as hybrid seed, inorganic fertilizer, pesticides, herbicides, and better management practices constitute the basic activities for crop production improvement (Audu and Aye, 2014). Next to Morocco, Ethiopia is the second largest barley producer in Africa, accounting for about 25 percent of the total barley production in the continent (FAO, 2014); and it is also recognized as a center of barley diversity, due to the germplasms of barley that has global importance like disease resistance (Vavilov, 1951, Qualset, 1975, Bonman, *et. al.,* 2005). Barley in Ethiopia is one of the staple food crops accounting for 6 percent of the per capita calorie consumption. It is also important in terms of the lives and livelihood of small farmers (CSA, 2014).

In this study, barley is the most important cereal crop grown widely by almost farm households in the study area, *Ankober*, *Basona* and *Angollela*, Barley in the study area used by the farm households for food, income and for their livestock feed (straw) as well as for their house wall construction mud plastering and roof thatching. Barley production in the study area has undertaken using improved barley technologies and traditional way of production system. Among many benefits of barley production, income from barley is one of the most important benefits of barley for the farm households. However, although barley is produce widely by the farm households, the intensity of income from it and the determinants affecting the intensity of income from barley are not well studied and documented. Hence, this study was designed and conducted to identify the determinants affecting the intensity of barley income and the contribution of barley technologies in enhancing income from barley.

In this analysis, to assess farm households' intensity of income determinants from barley, Censored Tobit model was employed. The predictors' description was also given and presented in Annex 1.7 of this study. As a result, seven continuous and 15 non-continuous predictors, a total of 22 were used after checking of multicollinearity problems, To check the multicollinearity problem among the continuous and non-continuous predictors, the variable inflation factor (VIF) and the correlation matrix were employed respectively. The test results have been presented in Table 67 (Annex) the correlation matrix result and in Table 68 (Annex) the (VIF) result. Since the result of multicollinearity tests showed that there were no serious problems, the selected predictors (continuous and non-continuous) were included in Censored Tobit regression model for further analysis to determine the effect of each predictor on the dependent variable (intensity of farm households' income from barley in Eth. Birr).

The Censored Tobit regression model analysis was conducted and the result of the analysis has indicated in Table 40. As it is indicated in Table 40, out of the total (22) predictors, (13) showed statistically significance effect on the dependent variable, income intensity from Barley in (Eth. Birr), among which, (2) predictors were continuous, and the rest (11) were non-continuous. In addition, among those (13) significant predictors, five (5) were affecting the dependent variable negatively; while the rest eight (8) were positively. Among the continuous predictors, market distance was affecting the dependent variable (negatively), which is as was presumed, at 5% significance level; and the predictor, food availability (Kcal) was affecting positively, as was hypothesized, at 1% significance level.

Regarding the effect of each of the predictors on the dependent variable, intensity of income from barley, as indicated in the Table 40 that, when the predictor, market distance (Km) increased by one unit (1Km), the intensity of farm households' income from barley in Eth. Birr showed to decrease with the probability of (0.06%), among the total (812) sample households, by 27 (Eth. Birr) among the total sample households and by 29.30 (Eth. Birr) among (805) uncensored respondents. Furthermore, the effect of the predictor household food availability in (Kcal) showed that, when the predictor increased by one unit (one Kcal), household's probability and intensity of income from barley showed to increase by 58% probability level among the total (812) sample households, by 0.0008 (Eth. Birr) among (812) total sample HHs and 0.0007 (Eth. Birr) among (805) uncensored sample households.

Furthermore, the predictors fertilizer and compost adoption affected the households' income intensity from barley in (Eth. Birr), positively and significantly. As a result, when the sample HHs adopt fertilizer, their intensity of income in (Eth. Birr) was increased with probability of 1.4% among the total (812) sample households, and with 686 (Eth. Birr) among the total (805) and 629 (Eth. Birr) among (812) uncensored sample households as indicated in the Table 40. Regarding the effect of compost adoption that showed positive correlation with the dependent variable (intensity of income from barley in Eth. Birr), which is as was presumed, with 10% significant level. The effect of compost adoption on the households' income intensity from barley was that, when the farm households adopted compost in barley production, their income from barley showed to increase with the probability level of 0.7%) among the total (812) sample households, by 335 (Eth. Birr) among the total (805) sample households and by 307 (Eth. Birr) among (812) uncensored sample households as indicated in the Table 40. The findings of this study are in line with the finding of Lin (1999) that adoption of hybrid rice (proxy for adoption of fertilizer and compost) technology had a positive and highly significant effect on household's income from rice production.

The predictors, adoption of weedicide, frequent hand weeding, farm land drainage and credit access were affect the dependent variable, farm households' income intensity negatively and significantly that differently from presumed. They correlated negatively at 1%, 5%, 1%, and at 5% significant level, respectively. The effect of each predictor, as indicated Table 40, when the sample farm households adopted weedicide, their intensity of income from barley showed to decrease by 1.6% probability level among total (812) sample households, by 753.43 (Eth. Birr) among uncensored (805) respondents, and by 691 (Eth. Birr) among total (812) sample households. Regarding frequent hand weeding, on the other hand affected the dependent variable in that, when the farm households adopted frequent hand weeding, their intensity of barley income decreased by 0.76% probability level among the total (812) sample households, by 366.61 (Eth. Birr) and by 336.23 (Eth. Birr) among the uncensored (805), and total (812) sample households. The predictors, farm land drainage and access to formal credit service correlated with sample farm households' intensity of income (Eth. Birr) from barley negatively and significantly, which were different from what were hypothesized, at 1% and 5% significant level, respectively which is consistence with the finding of Lin (1999).

When the predictor, farm land drainage was adopted, the farm household's intensity of income from barley showed to decrease by 1.25% of probability level among total (812) sample households, by 557.08 (Eth. Birr) among total (812) sample households and by 607.42 (Eth. Birr), among (805) uncensored sample households. The predictor, sample households' participation in off-farm activity was correlated with the dependent variable, farm households' intensity of income from barley in (Eth. Birr) positively and significantly at 5% probability level. Its effect on dependent variable was that, when farm households participated in off-farm activities, the intensity of income from barley showed to increase by 0.83% of probability level among (805) uncensored sample households, by 401.30 (Eth. Birr) among total (812) sample households, and by 368.04 (Eth. Birr). The finding of this study is in line with the evidence from Wanyama, *et. al.,* (2010) and Barret *et al.,* (2000) that households engaged in multiple activities (proxy for farm land drainage activity) to meet household's goals, to maximize benefits.

The predictors, sample farm households' participation in irrigation and *Belg* production, land rent-in practice, and in barley value addition practices were correlated positively and significantly with the dependent variable, sample farm households' intensity of income from barley in (Eth. Birr) as were hypothesized. The significance levels were 5%, 5%, 1% and 1%, respectively. The effect predictors on the dependent variable are indicated in Table 40. As a result, when the sample farm households' participated in irrigation and *Belg* production, in land rent-in and in barley value addition practices, their intensity of income from barley in (Eth. Birr) was increased. As indicated in Table 40, when farm HHs' participated in irrigation production, the intensity of income from barley was increased by 1.18% probability level among the total (812) sample households, by 525.53 (Eth. Birr) among the total (812) sample households, and by 573 (Eth. Birr) among (805) uncensored sample households, which showed consistence with the finding of Schwarze and Zeller (2005).

When farm HHs' participated in *Belg* production, the intensity of barley income increased by 0.80% probability level among (812) sample households, by 352 (Eth. Birr) among (812) sample households and by 383.83 (Eth. Birr) among (805) uncensored sample households. When farm HHs' participated in land rent-in practice that their intensity of income from barley increased with 2.33% probability level among the total (812) sample HHs', by 1033 (Eth. Birr) among the total (812) sample HHs', and by 1126 (Eth. Birr) among (805) uncensored sample households; and when the farm HHs' participated in barley value addition practices, the intensity of farm HHs' income from barley showed to increase with (3.40%) probability level among the total (812) sample HHs' by 1506 (Eth. Birr) among the total (812) sample HHs' by 1642 (Eth. Birr) among (805) uncensored sample HHs. The findings of this study is in line with the findings of Schwarze and Zeller (2005) that agricultural activities (proxies for agricultural activities such as irrigation, *Belg*, land rent-in, barley value additions) contributed 68% to total household's income (proxy for income from barley).

Table 40.Censored Tobit regression model analysis output to identify determinants affecting farmers' income intensity from barley (Eth. Birr)

Explanatory variables	Coef.	Std.dev.	t	P>|t|	Marginal effect		
					Prob. change among (812) sample HHs	Magnitude change among (812) sample HHs	Magnitude change among (805) uncensored
AGEHHHEAD	3.514115	6.485497	0.54	0.588	.0000711	3.161634	3.447317
HHHFORMEDUYR	2.166194	35.97728	0.06	0.952	.0000438	1.948915	2.125018
HHSIZEADEQV	-54.03536	54.27748	-1.00	0.320	-.0010937	-48.61538	-53.00823
LIVSTOCKSIZTLU	16.90286	25.26659	0.67	0.504	.0003421	15.20743	16.58156
FARMLADCULTHA	12.71804	172.63	0.07	0.941	.0002574	11.44236	12.47629
MARKDISTKM	-29.86263	11.88829	-2.51	0.012**	-.0006044	-26.86727	-29.29498
AVAILFOODPRODKC	.0007805	.000023	34.00	0.000***	1.58e-08	.0007022	.0007657
HHHEADSEX	-240.0197	195.1726	-1.23	0.219	-.0048579	-215.9447	-235.4573
HHADOPFERTBARL	699.2615	207.0829	3.38	0.001***	.0141528	629.1225	685.9696
HHADOPCOMPBARL	341.6311	182.1269	1.88	0.061*	.0069145	307.364	335.1372
HHADOPWEEDCIDE	-768.0327	183.73	-4.18	0.000***	-.0155447	-690.9956	-753.4335
HHADOPFREQPLOW	-229.6347	239.6506	-0.96	0.338	-.0046477	-206.6013	-225.2697
ADOPFRQWEDING	-373.7175	200.7888	-1.86	0.063*	-.0075639	-336.232	-366.6137
HHADOPIMPBARSED	-273.241	230.9822	-1.18	0.237	-.0055303	-245.8337	-268.0471
HHADOPFRMDRNGE	-619.1902	217.7448	-2.84	0.005***	-.0125322	-557.0826	-607.4203
HHFORMCREDACES	-512.5857	207.5657	-2.47	0.014**	-.0103746	-461.1711	-502.8422
HHACESBARLEXT	-194.2951	202.7103	-0.96	0.338	-.0039325	-174.8064	-190.6018
HHOFFARMPART	409.0735	189.289	2.16	0.031**	.0082795	368.0416	401.2976
HHPARTIRRGPROD	584.1197	280.0001	2.09	0.037**	.0118224	525.5299	573.0164
HHPARBELGPROD	391.2676	180.1586	2.17	0.030**	.0079191	352.0217	383.8302
LANDRENTINPART	1147.789	223.961	5.12	0.000***	.0232309	1032.661	1125.971
PARTINBARLYVAD	1673.502	198.5572	8.43	0.000***	.0338712	1505.642	1641.691
_cons	-405.0299	438.646	-0.92	0.356			
/sigma	2291.265	57.13548					
Obs. summary	7 left-censored observations at barley income in Eth. Birr <=0, 805 uncensored observations, 0 right-censored observations						
Tobit regression		Number of obs = 812				Prob > chi2 = 0.0000	
Log likelihood = -7376.2331		LR chi2(22) = 1012.95				Pseudo R2 = 0.0643	

Source: own computation from 2014/2015 HH survey data; and *, **, ***, which show significance level at (10%, 5%, and 1%) respectively;

5.7. Barley technologies adoption contribution in barley income intensity (Eth. Birr)

Agricultural production system in Ethiopia is small-scale, cereal crops are the most important food crops that the majority of the rural households produce for consumption and receive income by selling the produce. Production side investment such as agricultural input credit, rural education, training and improving storage facilities prolonging the credit repayment period until the seasonal crop prices rise might increase the benefit of smallholders from marketed surplus Producer’s production technology choice might affect the productivity. Increased productivity gain is not an end by itself and the production should be linked to the market for driving profits. Increasing farmers’ potential in productivity and marketable surplus requires substantial diffusion of modern agricultural technologies (Tigist, 2017).

Barley is important in terms of the lives and livelihood of small farmers. It is widely grown crop over broad environmental conditions (Martin et al., 2006). In the highland of Ethiopia, barley is predominantly cultivated between 2000 and 3000 masl (Berhane, *et. al.,* 1996). It. It has persisted as a major cereal crop through many centuries (Martin et al., 2006). Barley has a long history of cultivation in Ethiopia and it is reported to have coincided with the beginning of plow (Zemede, 2000). In the highland of Ethiopia, under extreme marginal conditions (drought, frost, poor soil fertility and highly degraded mountain slopes) barely is the most dependable cereal, cultivated better than other cereal crops (Ceccarelli *et al.*, 1999).

Barley is one of the most important grain crops in Ethiopia. However, its productivity is low due to poor soil fertility, low yielding varieties, weed competition, diseases, insect pests, frost and hail, waterlogging, and shortages of power and implements, poor agronomic practices (Berhane, *et. al.,* 1996; Chilot, *et. al.,* 1998; Woldeyesu, *et al.,* 2002). It is preferred by subsistence farmers because of its early maturity and ability to grow better on marginal farms than other cereals, as well as its suitability for growing during the Belg season—the short rainy season and during the main rainy season- *Meher* (Mulatu and Grando, eds, 2011).

In the study area barley is widely produced for the farm households’ food consumption, to use its straw for their livestock (which is one of the major livelihood sources for the farm households in the study area), for other purposes such as for roof thatching, for house wall construction by mixing its straw with mud and for mud plastering of the wall. Farm households’ sell barley for their income to cover the households’ different expenditures.

Therefore, barley also produced for income source. However, due to several reasons, mentioned in the above, the yield of barley, thereby, the income from barley is not as such satisfactory. Use of improved technologies in barley production can increase the income from barley as a result of yield improvement. The two sample t-test showed that those users/adopters are better in their income as compared to the non-adopters/non-adopters.

Table 41.The two sample t-test result on the contribution of barley technologies adoption on farm households' intensity of income from barley (Eth. Birr)

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	3609.459	272.0023	2339.852	3067.36	4151.559
Adopters	738	4884.879	161.6859	4392.385	4567.459	5202.299
combined	812	4768.646	149.5492	4261.497	4475.097	5062.196
diff		-1275.42	518.0182		-2292.236	-258.6033

diff = mean(Non-adop) - mean(Adopters) t = -2.4621
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.0070 Pr(|T| > |t|) = 0.0140 Pr(T > t) = 0.9930

Source: own computation from 2014/2015 HH survey data

As a result, as shown in the Table 41, the annual income of barley technologies adopters from barley is higher by (Eth. Birr. 1275.42) than non-adopters, which revealed that adoption/use of improved agricultural technologies is important to increase farm households' income. Therefore, efforts to increase the farm households' adoption of barley technologies is vital to improve the livelihoods of farm households and, thereby, to alleviate their poverty

CHAPTER SIX: DETERMINANTS OF AGGREGATE AND BARLEY FOOD AVAILABILITY AND THEIR CONTRIBUTION IN ADOPTION OF BARLEY TECHNOLOGIES

6.1. Farm households' aggregate food availability and barley technologies adoption contribution in food availability

Availability of food is an essential factor to be considered in ensuring the sustainable food security (Aborisade and Bach, 2014). Even though aggregate food availability is insufficient to ensure either access to proper utilization of nutrients to achieve food security, it is a necessary condition for food security (Barrett, 2001). It can be seen as a physical availability of food, which can be accessed by the household through production, purchase or through some other means (Hiwot, 2014). According to FAO (2013) food availability is a dimension of food security that plays a prominent role that household's food availability (supply) is possible by enabling household' to produce or buy their own food to meet their food requirement. Farmers in the highlands od Ethiopian are both producer and consumer of their cereal harvests, and they grow modern varieties, which include barley (Benin, et.al., 2003)

In the study area in Andover, bison, and *Angollela woreda*, which are located in the highlands of central Ethiopia, in *Semen Shewa* Zone (*Amhara* region), barley is the most important and widely produced cereal crop used by the farm households for their income source and food consumption. The production of barley in the study area is with and without using improved barley technologies. The different barley technologies that include barley farm land frequent plow, fertilizer adoption, manure compost, frequent hand weeding of barley, weedicide, barley farm land drainage, improved barley seed adoption, and use of improved farm tools. The finding, in this study showed that, out of the total (812) sample households 738 (90.89%) were adopters of one or more barley technologies and the rest 74 (9.11%) were non-adopters of barley technologies.

Furthermore, in this study, adoption of the aforementioned barley technologies and the farm households' food availability status showed significant association in chi-square test analysis as indicated in Table 42. As the chi-square test result showed that fertilizer adoption and farm households' food availability status showed the significant association with (p-value, 0.009), which is at 1% significant level. Furthermore, the chi-square-test also showed the significant association between farm households' food availability and compost, Frequent plow (3≤), Frequent weeding (2≤) and farm land drainage, but not between farm households' food availability status and weedicide adoption and Improved barley seed adoption. As it is indicated in the Table 42, the total aggregate barley technologies adoption and the aggregate food availability status of farm households showed the significant association with (p value= 0.012), which is at 1% significant level. Therefore, from the chi-square test, it is possible to conclude that adoption of barley technologies is vital in improving the yield of barley technologies, thereby, the food availability and well-being of the farm households

Table 42.Chi-square test to measure the association between farm households' barley technologies adoption and food availability status (Kcal)

Barley technologies adoption status		HHs' food availability status (below/equal and above (2550 Kcal)		Chi-square test result	
		Below	Equal/above	X^2 -Value	Sig.
Fertilizer	Adopters (583)	186	397	6.085	.009
	Non-adopters (229)	94	135		
compost	Adopters (453)	129	324	16.359	.000
	Non-adopters(359)	151	208		
weedicide	Adopters (343)	114	229	0.408	.287
	Non-adopters (469)	166	303		
Frequent plow (3≤)	Adopters (600)	197	403	2.767	.058
	Non-adopters (212)	83	129		
Frequent hand weeding (2≤)	Adopters (382)	119	263	3.543	.035
	Non-adopters (430)	161	269		
Improved barley seed	Adopters (160)	51	109	.600	.249
	Non-adopters (652)	229	423		
Farm land drainage	Adopters (223)	63	160	5.284	.013
	Non-adopters (589)	217	372		
Total barley technologies	Adopters (738)	245	493	5.918	.012
	Non-adopters (74)	35	39		
	Total sample HHs (812)	280	532		

Source: own computation from 2014/2015 household survey; numbers in parentheses represent the adopters and non-adopters;

Furthermore, the two sample t-test result has also shown the contribution/role of barley technologies adoption in enhancing farm households' food availability status. As it indicated in the Table 43, the mean Kcal available food of adopter sample households is higher by 231102.20 Kcal than the available food of non-adopter farm households.

Table 43.The two-sample t-test with equal variances to compare the barley food availability difference among adopters and non-adopters of barley technologies

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	2403347	181369.2	1560197	2041879	2764816
Adopters	738	2634450	93364.45	2536353	2451158	2817742
combined	812	2613389	86457.63	2463663	2443681	2783096
diff		-231102.2	300486.3		-820925.9	358721.5

diff = mean(Non-adop) - mean(Adopters) t = -0.7691
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Pr(T < t) = 0.2210
Ha: diff != 0 Pr(|T| > |t|) = 0.4421
Ha: diff > 0 Pr(T > t) = 0.7790

Source: own computation from own survey data

In addition, the two sample t-test analysis result showed the contribution of barley technologies adoption on the sample farm households food availability from barley as indicated in Table 44.

Table 44.Two-sample t-test with equal variances to compare the barley food availability difference among adopters and non-adopters of barley technologies

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	4742704	399006.7	3432385	3947485	5537923
Adopters	738	5926937	156577.9	4253619	5619545	6234329
combined	812	5819014	147303.8	4197512	5529873	6108156
diff		-1184233	510453		-2186200	-182266.3

diff = mean(Non-adop) - mean(Adopters) t = -2.3200
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Pr(T < t) = 0.0103
Ha: diff != 0 Pr(|T| > |t|) = 0.0206
Ha: diff > 0 Pr(T > t) = 0.9897

Source: own computation from own survey data

As it is indicated in the Table 44, the adopter sample households' mean Kcal food available from barley is higher by 1184233 Kcal than non-adopter farm households' available food from barley. The, two sample t-test analysis result showed that adoption of barley technologies is important in enhancing barley yield, thereby, farm households' food availability from barley production. The chi-square test and the two sample t-tests showed that adoption of barley technologies is vital in improving farm households' food availability status. Hence, efforts towards improved technologies dissemination is an indispensable task for those who are involved in agricultural and farmers' development activities as well as at government officials' role in designing policies and development programs and strategies.

In this study, the sample farm households' distribution based on their food availability status and adoption of different barley technologies such barley farm land frequent plow, fertilizer adoption, manure compost, frequent hand weeding of barley, weedicide, barley farm land drainage, improved barley seed adoption, and improved farm tools were assessed and summarized in the Table 45. In addition, the sample farm households' distribution based on the minimum food Kcal requirement and availability using (2550Kcal) per day per adult equivalent person, according to CSA and WFP (2014) was analyzed and summarized in the Table 45. Based on the minimum food Kcal requirement (2550Kcal) per day per adult equivalent and based on the available food in Kcal at household level, the farm households were grouped in to those households with below minimum food availability status and those with equal/above minimum food availability standard. As a result, out of the total (812) sample households, 34.48% were in below food availability status; and 65.52% were with food availability status equal/above the minimum status, which revealed that the majority of households were with equal/above minimum food availability status.

On the other hand, sample households were distributed based on their barley technologies adoption and food availability status, as indicated in Table 45. Hence, based on barley technologies adoption, out of the total (738) adopters, (33.20%) were in below, while the rest (66.80%) were with equal/above minimum food availability status, which showed that, the majority of adopter farm households were with better food availability status. Regarding the total (74) non-adopters, (47%) were below, while the rest (53%) were with equal/above the minimum food availability status, which showed that the majority of them were with equal and above the minimum food availability in Kcal. Although the majority farm households from adopters and non-adopters were with better food availability, the proportion from adopters (67%) were larger than from the non-adopters (53%). Hence, adoption of improved technologies is vital to enhance farm households' food availability status.

Table 45. Farmers' distribution by technology adoption and food availability status (Kcal)

Barley technologies adopted by farm HHs	Sample HHs food availability status by technology adoption		Out of the total (812) sample HHs
	below (2550) Kcal	Equal and above (2550) Kcal	
Barley farm land frequent plow	197 (32.83)	403 (67.17)	600 (73.89)
Fertilizer adoption	186 (31.90)	397 (68.10)	583 (71.80)
Manure compost	129 (28.48)	324 (71.52)	453 (55.80)
Frequent hand weeding of barley	119 (31.15)	263 (68.85)	382 (47.04)
Weedicide	114 (33.24)	229 (66.76)	343 (42.24)
Barley farm land drainage	63 (28.25)	160 (71.75)	223 (27.46)
Improved barley seed adoption	51 (31.88)	109 (68.12)	160 (19.04)
Use of improved farm tools	38 (25)	114 (75)	152 (18.72)

Source: own organization from household survey (2014/2015); and numbers in parenthesis represent percent

Improved barley technologies, adopted by farm HHs' in the study area, plaid significant role in enhancing HHs' aggregate food availability (Kcal). The adopted barley technologies role or contribution on farm HHs' food availability has summarized in Table 45. As a result, farm land frequent plowing practice was adopted by (600) sample farm households, and out of which, (32.83%) were below the minimum food availability status, while the rest (67.17%) with equal/above minimum food availability status. Adopters of chemical fertilizer were (583), out of which, (31.90%) were below the minimum food availability status; while the rest (68.10%) were with equal/above minimum food availability status.

The manure compost adopters of sample farm households were (453), out of which (28.48%) were below the minimum and the rest (71.52%) were with equal and above the minimum food availability status; and the frequent hand weeding of barley crop adopter farm households were (382), out of which, (31.15%) were below the minimum standard, while the rest (68.85%) were with equal and above the minimum food availability standard (2550Kcal). Moreover, out of the total (343) weedicide adopters, (33.24%) were below the minimum food availability standard; while the rest (66.76%) were with equal and above the minimum food availability standard (2550Kcal). The farmland drainage adopters were (223), out of which, 28.25% were below the minimum standard, while the rest (71.75%) were with equal/above minimum food availability status. Improved barley seed adopters were (343), out of which, (33.24%) were below the minimum food availability standard; while the rest (66.76%) were with equal/above the minimum food availability standard.

Furthermore, adopters of improved farm tools (broad bed molder/BBM, small scale irrigation pump, and others) were adopted by (152), out of which (25%) were below the minimum 2550 Kcal food availability threshold; while the rest (75%) were with equal and above the minimum food availability threshold as indicated in Table 45. Results in this analysis showed that, the proportion of adopters with equal and above the minimum food availability threshold were higher than the proportion of non-adopters. Therefore, adoption of improved technologies in general and barley technologies in particular plaid significant role in enhancing the food availability status of adopter farm households.

The farm households' distribution based on the food availability status and their adoption of barley technologies woreda and sex has summarized in Table 46. As a result, out of the total (604) male respondents, (33.77%) were below the minimum food availability standard, while the rest (66.23%) were with equal/above the minimum food availability standard, which revealed that the majority of male sample households were with equal/above the minimum food availability standard. Regarding the total (208) female sample households, (36.54%) were with below, while the rest (63.46%) were with equal/above the minimum food availability standard, as shown in the Table 46.

Table 46.Table. Adopters and non-adopters' distribution by food availability status (Kcal)

Respondents Distribution		Sample HHs food availability status below or with equal/above minimum 2550 (Kcal)		Out of the total (812) sample HHs
		Below	Equal/above	
Barley technologies adoption and food availability	Non-Adopters	35 (47.30)	39 (52.70)	74 (9.11)
	Adopters	245 (33.20)	493(66.80)	738 (90.89
Study *woredas* and HHs' food availability	*Ankober*	136 (50.37)	134 (49.63)	270 (33.25)
	Basona	87 (32)	185 (68)	272 (33.50)
	Angollela	57 (21.11)	213 (78.89)	270 (33.25)
Respondents' sex and food availability	Male	204 (33.77)	400 (66.23)	604 (74.38)
	Female	76 (36.54)	132 (63.46)	208 (25.62)
Total sample HHs		280 (34.48)	532 (65.52)	812 (100)

Source: own organization from household survey (2014/2015); and numbers in parenthesis represent percent

Furthermore, the sample farm households' food availability distribution by the study *woreda* has also summarized in the Table 46. As a result, out of the total (270) sample households from *Ankober woreda*, (50.37%) were with food availability below the minimum standard, while the rest (49.63%) were with food availability status equal and above the minimum standard (2550Kcal), according to CSA and WFP (2014). The results revealed that in *Ankober woreda*, almost half of the proportion of the household were in below and the other half were with equal/above the minimum food availability standard (2550Kcal).

The sample farm households' food availability distribution in *Basona woreda*, as shown in Table 46, out of the total (272) sample households, (32%) were below the minimum food availability status, while the rest (68%) were with equal/above the minimum food availability standard, which revealed that, the majority of sample households in *Basona woreda* were with equal/above the minimum food availability status. The sample households' food availability status in *Angollela woreda*, as shown in Table 46, out of the total (270) sample households, (21.11%) were below the minimum food availability status, while the rest (78.89%) were with equal and above the minimum food availability status (2550Kcal), which revealed that the majority of sample households in *Angollela woreda* were with equal/above the minimum food availability status. In general households in *Angollela* and *Basona* were better in food availability status as compared to *Ankober woreda*, as shown in Table 46.

Furthermore, the sample households' mean and std. dev. of food availability in Kcal and its distribution has summarized by the sample households' technology adoption status, by the study *woreda* and by the sex of the sample households, as indicated in the Table 47. As a result, the adopters and non-adopters' total aggregate mean Kcal food availability were 5926937.13 and 4742704.22 respectively, which showed that the mean food Kcal of adopters is higher than the non-adopters with mean difference of 1184233 Kcal. Therefore, adopters are higher in mean food Kcal availability as compared to the non-adopters. Furthermore, the sample households' mean food availability in Kcal from barley has summarized, as shown in the Table 47 that, the mean food availability in Kcal of adopters from barley was 2634449.64 and that of non-adopters from barley in Kcal was 2403347.43, which revealed that the adopters mean Kcal food availability showed higher than non-adopters with 231102.204 mean Kcal food availability difference as indicated in the Table 47.

The mean and std. dev. of the Kcal food availability of the male and female sample household have summarized in the Table 47. As a result, the aggregate mean Kcal food availability of the male sample households was 6110664.91, and that of female HHs was 4972106.27, which showed that the mean Kcal food availability of male headed households is higher than the mean Kcal food availability of the female sample households.

Table 47. The sample households' mean food availability distribution

Respondents' mean food availability		**Sample HHs' aggregate mean food availability (Kcal)**		**Sample HHs' mean barley food availability (Kcal)**	
		mean	**St.dev.**	**mean**	**St. dev.**
By barley technologies adopted	Adopters (738)	5926937.13	4253618.96	2634449.64	2536353.134
	Non-Adopters (74)	4742704.22	3432385.213	2403347.43	1560197.175
Mean difference (Kcal)		**1184233**		**231102.204**	
By study woredas	Ankober (270)	5421041.30	3836735.08	2123484.34	1392260.340
	Basona (272)	5576329.80	4536491.71	2626152.20	3422283.027
	Angollela (270)	6461469.86	4127130.61	3090434.72	2022917.036
By sex of respondents	Male (604)	6110664.91	4054764.87	2689002.52	3707047.317
	Female (208)	4972106.27	4490751.14	2393817.40	1850264.792
Mean difference (Kcal)		**1138558.64**		**295185.12**	
Total sample HHs		5819014.42	4197512.07	2613388.60	2463663.18

Source: computed from 2014/2015 households' survey data

The mean Kcal food availability difference between male and female sample households is 1138558.64 as indicated in the Table 47. On the other hand, the mean and std. dev. of the male and female households' barley food availability in Kcal has shown in the Table 47. Therefore, the male mean food availability in Kcal is 2689002.52 and that of female sample households' is 2393817.40. Hence, the result revealed that the male mean food availability from barley is higher than that of female. The barley food availability mean difference in Kcal between male and female sample households is 295185.12 as indicated in the Table 47.

Regarding the Kcal mean and std. dev. of the sample households' aggregate and barley food availability distribution by the study *woreda* has summarized as shown in the Table 47. As a result, the aggregate mean Kcal food availability of sample households in *Ankober woreda* is 5421041.30, in *Basdona woreda* is 5576329.80 and in *Angollela woreda* is 6461469.86, which revealed that the highest aggregate mean food availability in *Angollela woreda* is higher than the other two *woredas (Ankober* and *Basona woreda).* Regarding the mean food availability in Kcal from barley among the study *woredas* as indicated in Table 47 is that, 2123484.34 in *Ankober woreda*, 2626152.20 in *Basona woreda* and 3090434.72 mean Kcal in *Angollela woreda*. The results revealed that the mean barley food availability in Kcal in *Angollela woreda* is higher and the lower is in *Ankober woreda* as indicated in Table 47.

The sample households' aggregate food availability sources and food availability from barley are summarized in Table 48. The total sample households' food availability in Kcal is (4725039711), out of which, the available food from different crops covered (95.28%), from livestock (0.75%), and from other different sources such as (aid, gift, etc.,) covered (3.97%), which revealed that almost all the total food availability of the sample households in the study area comes from crops, out of which, the most important food availability source is barley. Furthermore, as indicated in Table 48, the contribution/share of barley in total aggregate food availability of sample farm households, and in total cereal crop food availability in (Kcal), were calculated and summarized in Table 48. As a result, the share of barley in total aggregate food availability was (44.91%), which showed that, out of the total aggregate food availability, the highest proportion of food Kcal came from barley. In addition, the share of barley in total crop food availability (Kcal) as shown in Table 48 was (47.14%), which revealed that closer to half of the food Kcal comes from barley.

Table 48. Sample households' total income and incomes from different sources (Eth. Birr)

HHs' different food sources	Farm HHs' food availability (Kcal)	Share of available food (percent)
Total food from different crop sources	4501933655	95.28
Total Livestock food	35257958.56	0.75
Food from other sources (aid, gift, etc.,)	187848097.6	3.97
Total food available	**4725039711**	**100**
Total HHs available food except barley	2602968170	55.09
Total barley food	2122071541	44.91
Total HHs food including barley	**4725039711**	**100**
Total food from different crops except barley	2379862114	52.86
Total food from Barley	2122071541	47.14
Total food from different crops	**4501933655**	**100**
Available total cereal food except barley	1559824130	42.36
Available total barley food	2122071541	57.64
Total cereal food including barley	**3681895671**	**100**

Source: own computation from 2014/2015 HHs' survey

In addition, the share/contribution of barley in cereal crop food availability in (Kcal) as indicated in the Table 48 is (57.64%), which revealed that, out of the total cereal food Kcal, the higher proportion is from barley. Therefore, the share of barley in sample farm households' food availability is high and the crop barley is very significant in farm households' food availability. Therefore, barley production should be enhanced through use of improved technologies. The results of the analysis in this study is in line with the finding of Magrini and Vigani (2015) that the effect of maize technologies on food security is positive and significant. Hence, the overall, results suggested that agricultural improved technologies have positive and significant impact on food security.

To assess the sample households' food availability status, the association and effect of barley technologies adoption on the aggregate and barley food availability of households, descriptive statistics that include percentage, frequency, mean, std. dev., chi-square test, two sample t-test, cross tabulation were employed. In addition to these analyses, further analyses were conducted were conducted: (i) to identify determinants affecting the sample farm households' total aggregate food availability status using logistic regression model, (ii) to identify those determinants affecting the sample farm households' total aggregate food availability intensity in Kcal using multiple linear regression, and (iii) to identify those determinants affecting the sample farm households' intensity of food availability from barley in (Kcal) using Censored Tobit regression model. For these analyses, the dependent and independent variables description and the models specifications are given in the research methodology section of this study.

6.2. Determinants affecting the farm households' total aggregate food availability status

In the analysis of farm households' aggregate food availability status determinants, Logistic regression model was employed. The dependent variable comprised two categories that include the farm households whose aggregate food availability status is below the minimum standard (2550 Kcal) was represented by Zero (0); and those whose food availability status equal/above the minimum standard (2550 Kcal) was represented by one (1). The independent variables hypothesized to affect the dependent variable were continuous and non-continuous, in total they were 17 (seventeen), but, out of which sixteen (16) explanatory variables were included in the model. One predictor, which is market distance, showed multicollinearity problem and was discarded from the model not to be included in further model analysis.

Among, continuous predictors, market distance (Km) showed multicollinearity. As a result, it was not included in the binary logit regression model for further analysis. Explanatory variables, before they were included in the logit regression model, for further analysis, test for the existence multicollinearity problem were undertaken using variable inflation factor (VIF) for continuous predictors; and correlation matrix analysis was conducted for non-continuous predictors multicollinearity test. Both test results, the VIF and correlation matrix tests were summarized in Table 69 (Annex) and in Table 70 (Annex) respectively.

In the variable inflation factor test analysis, the predictor, market distance (Km) showed multicollinearity problem. Hence, it was discarded not to be included in Logistic regression model for further analysis. The rest, sixteen (16) predictors, that include (6) continuous and (10) non-continuous predictors, which were free from multicollinearity problem were included in logit regression model for further analysis. Then, the model was run and the result of the model analysis showed that, out of these (16) predictors, four continuous and four non-continuous, a total of eight (8) predictors showed significant effects on the dependent variable, aggregate food availability (Kcal) of sample households, as indicated in Table 49. As the logistic regression model output showed, among the continuous significant explanatory variables included in the model, the predictor (household size) affected the dependent variable negatively and significantly as was presumed with 1% significant level.

The rest continuous and significant predictors that include (livestock size, farm land size, and households' income in Eth. Birr) were affect the dependent variable positively as were presumed with 5%, 1% and 1% significant level respectively. Furthermore, among the significant non-continuous explanatory variables that were included in the model, the predictor (frequent plow) affected the dependent variable negatively and differently from what was presumed, with 10% significant level. The other significant non-continuous predictors affecting the dependent variable include (compost adoption, frequent weeding, and access to agricultural extension service) affected the dependent variable positively at 10%, 1% and 10% significant level respectively. Among the significant predictors, household size (adult equiv.) has affected the dependent variable (households' aggregate food availability status) negatively and significantly as hypothesized at 1% sign. level.

Table 49. Logistic model analysis output on respondents' aggregate food availability status

Predictors	Coef.	Std. Err.	z	P>|z|	Marginal effect
AGEHHHEAD	.0041908	.0073	0.57	0.566	.0007394
HHHFORMEDUYR	.019524	.0411491	0.47	0.635	.0034446
HHSIZEADEQV	-.9132766	.0843185	-10.83	0.000***	-.1611279
LIVSTOCKIZETLU	.0805159	.0340111	2.37	0.018**	.0142053
FARMLANDSIZEHA	.7836657	.2084242	3.76	0.000***	.1382609
ANAVINCOMEBIR	.0001308	.0000153	8.57	0.000***	.0000231
HHHEADSEX	.1606141	.2260516	0.71	0.477	.0289349
ADOPFERTBARL	-.2671743	.22755	-1.17	0.240	-.0456407
ADOPCOMPBARL	.372086	.203222	1.83	0.067*	.066385
ADOPWEEDCIDE	.1668505	.2148896	0.78	0.437	.0292286
ADOPFREQPLOW	-.4687788	.2689303	-1.74	0.081*	-.0776649
ADOPFRQWEDING	.6760443	.2274143	2.97	0.003***	.1178661
ADOPIMPBARSEED	-.2374428	.2789915	-0.85	0.395	-.0435082
ADOPFRMDRNAGE	.0403176	.2390399	0.17	0.866	.0070781
FORMCREDACES	-.2540888	.2485988	-1.02	0.307	-.0465201
ACCESAGREXT	.6123854	.3375965	1.81	0.070*	.1217953
_cons	.6704912	.5253225	1.28	0.202	

```
Logistic regression                         Number of obs   =        812
                                            LR chi2(16)     =     358.28
                                            Prob > chi2     =     0.0000
Log likelihood = -343.93826                 Pseudo R2       =     0.3425
```

Source: own computation from 2014/2015 HHs survey data
***, **, *, Represent, the 1%, 5%, 10% significant level respectively;

Therefore, when the household size increased (in adult equivt.) by one unit, the food availability status of the farm household has decreased by 16%, which suggests that the higher the household size, the higher the food consumption, thereby the households' food availability status showed to decrease. This finding is in line with the findings of Babatunde *et al.*, (2007), Kidane, 2005), Fekede, *et. al.*, (2016), Tesfaye (2003), Asefech and Nigatu (2007), Haile, *et. al.*, (2005); and disagreed with the findings of Abu and Soom (2016), Prakash, *et. al.*, (2012), Ibok, *et. al.*, (2014), Ahmed, *et. al.*, (2015).

The farm households' aggregate food availability status (the dependent variable) affected by the farm land size ownership of the HHs, positively and significantly as it was hypothesized, with 1% level. As the logistic regression model analysis result output showed that, when the farm land size increased by one unit (1Ha), the household's aggregate food availability status showed to increase by 14% probability level, which suggests that the larger the farm land ownership owned by the farm households, is the better the farm households in their food availability status. This finding is consistence with the findings of Ahmed, *et. al.* (2015); Adeniyi and Ojo (2013); Asogwa and Umeh (2012), Haile, *et. al.*, (2005), Reddy, *et. al* (2004), Ikpi, and Kormawa (2004) that all concluded that farm households with higher farm land size are better in their food availability status, which means the higher the farm land size ownership the better the farm households in their food availability (food security).

The predictors farm households' annual total/aggregate income in (Eth. Birr), affected the dependent variable (farm households' aggregate food availability status) positively and significantly, as it was presumed, at 1% significant level. As indicated in the Table 49, when the farm households' income in (Eth. Birr) increased by one unit (one Eth. Birr), their food availability status showed to increase by 0.0023%. Hence, households with better income status showed better in their aggregate food availability status. This finding is in line with the findings of Ahmed, *et. al*., (2017), Henri-Ukoha, *et, al*., (2013), Abu and Soom (2016), Tekle and Berhanu (2015); Ibok, *et. al*, (2014); Ahmed, *et. al*., (2015, Arene and Anyaeji (2010), Adeniyi and Ojo (2013), Asogwa and Umeh (2012), Hamilton, *et. al.*, (1997).

The predictor, livestock size in (TLU) affected the dependent variable, farm households aggregate food availability status in (Kcal) positively and significantly as was presumed with 5% significant level. As indicated in the Table 49, when the farm households' livestock size in (TLU) increased by one unit (one TLU), their food availability status showed to increase by 1.4%. Hence, households with better livestock size (TLU) showed better in their aggregate food availability status. This finding is in line with the findings of (Joshi & Joshi (2017) that the number of livestock owned by the household had a significant positive influence on household food security. Livestock have many socio-economic benefits to farm households and are perceived as indicators of wealth; therefore, the possession of greater numbers of livestock implies a higher likelihood of food security Possession of livestock mitigates the vulnerability of households during crop failures and other calamities.

The predictor, compost adoption affected the dependent variable, farm households aggregate food availability status positively and significantly as was presumed with 10% significant level. As indicated in the Table 49, when the farm households adopt compost in their barley production, their aggregate food availability status showed to increase by 6.64%. Hence compost adoption is vital in enhancing households' aggregate food availability status. Furthermore, the predictor, adoption of frequent weeding of barley crop (two or more times) affected the dependent variable, farm households aggregate food availability status in (Kcal) positively and significantly, with 1% significant level. As indicated in the Table 49, when the farm households adopt the frequent hand weeding of barley (two or more times), their aggregate food availability status showed to increase by 12% which revealed that the frequent hand weeding of barley increase the yield of barley, thereby, the aggregate food availability status of the farm households. The findings of this study on compost and frequent hand weeding (two or more times) are in line with the finding of Tessema (2015).

The predictor, adoption of frequent plowing of barley farm land (three or more times) affected the dependent variable, farm households aggregate food availability status negatively and significantly at 10% level. The negative effect of the predictor, adoption of frequent plow of barley farm land was differently from what was presumed. Its effect on the dependent variable, as indicated in the Table 50, when the farm households adopt the frequent barley farm land plow, their aggregate food availability status showed to decrease by 8.10%, which might be due to water looing problem since frequent plow help to avoid excess water from the farm. Hence compost adoption is vital in enhancing households' aggregate food availability status. The extension service access and farm households' food availability in (Kcal) were correlate positively and significantly, as was presumed at 10% significant level. The positive effect of the predictor, access to agricultural extension service, as indicated in Table 50, when the farm households' have access to extension service, their aggregate food availability status increased by 12.18%, which revealed that access to agricultural extension service is vital to increase farm households' aggregate food availability status. This finding is in line with the finding of Tessema (2015) that the use of extension service increases the farm households' land productivity by 0.14 units, thereby, food availability.

6.3. Determinants of farm households' aggregate food availability (Kcal)

In the analysis of determinants of farm households' aggregate food availability intensity (Kcal), the dependent variable, multiple linear regression model was employed. The independent variables hypothesized to affect the dependent variable, which is the intensity of total aggregate annual farm households' food availability in (Kcal), were grouped in to two that include the continuous and non-continuous explanatory variables, which in total were twenty-one (21), but, out of which, one predictor, market distance was discarded, since it showed multicollinearity problem. Then only twenty (20) explanatory variables were included in multiple regression model. The multicollinearity test result have been summarized in Table 71 (Annex) for the non-continuous variables; and in Table 72 (Annex) for continuous predictors.

As shown in the variable inflation factor (VIF) analysis output in Table 69, market distance (Km) showed multicollinearity problem. As a result, it was discarded not to be included in the multi-linear regression model and from further model analysis. Regarding the multicollinearity test result of correlation matrix among the non-continuous variables as shown in Table 70, there was no multicollinearity problem. Hence, all the selected non-continuous predictors were included in the model for further analysis. Finally, among the selected 21 predictors, only 20 predictors that were free from multicollinearity problem were included in the model for further analyses. Among the (20) explanatory variables, that were free from multicollinearity problems were grouped in to two (continuous and non-continuous) predictors.

The continuous predictors included in the model were six (6), which include (HH age in Log years, HH education in Log years, Livestock size in Log TLU, Farm land size in Ha, HH size in adult equivalent, HH total annual aggregate income in Log Eth. Birr); and the rest ten (10) predictors were non-continuous were included in the multiple regression model. Among six (6) continuous predictors, after checking multicollinearity problem, only three (3) were include in the multiple linear regression model analysis were livestock size (TLU), farm land size (Ha), and HHs' annual total aggregate income in (Eth. Birr) showed significance effect on the dependent variable (households' intensity of total aggregate food availability in Kcal).

All continuous and significant predictors affected the dependent variable positively as was presumed, with 5%, 1% and 1% significant level, respectively. that include were (HHs participation in barley value addition practices, HH head sex, access to barley extension, frequent adoption, access to formal credit service, HHs participation in land rent-in, compost adoption, participation in *Belg* production, weedicide adoption, improved barley seed adoption, off-farm participation, farm drainage practice adoption, frequent hand adoption, HHs' participation in barley selling options).

Regarding the non-continuous predictors, out of the total fourteen (14) of them, only seven (7), which include (weedicide adoption, frequent hand weeding adoption, farm HHs' access to formal credit service, participation in *Belg* production, participation in land rent-in participation, participation in barley selling options, farm HHs' access to barley extension service) were affect the dependent variable significantly, as indicated in the Table 50. The significant non-continuous predictors, except farm HHs' access to formal credit service, which affected the dependent variable negatively and differently from what was presumed, all the rest non-continuous predictors were affecting the dependent variable positively, as were presumed, with significant level indicated in the Table 50.

Among six continuous explanatory variables included in the multiple linear regression model, livestock size (TLU), farm land size (Ha), and farm HHs' income in (Log Eth. Birr) were affecting the dependent variable positively and significantly as were presumed, with 5%, 1% and 1% significant level respectively. The effects of these significant predictors on the dependent variable showed that, when the farm households' livestock size (TLU) increased by one unit (one TLU), the farm households' intensity of aggregate food availability in (Log Kcal) showed to increase by 0.54 units (Log Kcal). This finding is consistent with the results of other studies such as Abebaw (2003); Tesfaye (2005); Mulugeta (2002).

The predictor, farm land size in (Ha), affected the dependent variable, farm households' intensity of aggregate food availability to increase by 0.18 unit, which suggested that, when farm land size of the household increase by one unit (one hectare), the farm households' intensity of food availability (in Kcal) showed to increase by 0.18 units (Log Kcal). This finding has agreed with the findings of Tesfaye (2005), Yilima (2005), Mulugeta (2002), Thewodros (2007). Adom, (2014), Haile (2005), Feleke (2003), Hiwot (2014), Abu and Soom (2016), Adeniyi and Ojo (2013), who found out that farm land size increases the likelihood of households being food secured.

Table 50. Multiple linear regression model analysis output on determinants affecting farm households' aggregate intensity of food availability (Log Kcal)

Predictors	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
LOGAGEYR	-.0204929	.1466107	-0.14	0.889	-.3082849	.2672991
EDUYRSLOG	-.0108189	.0590783	-0.18	0.855	-.1267876	.1051499
HHSIZEADEQV	-.0291124	.0285717	-1.02	0.309	-.0851978	.026973
LOGLIVSTLU	.5382764	.2378648	2.26	0.024**	.0713554	1.005197
FARMLANDSIZHA	.17979	.0327523	5.49	0.000***	.1154983	.2440817
INCOMEBIRRLOG	.464667	.0236571	19.64	0.000***	.4182288	.5111052
HHHEADSEX	.0218253	.037828	0.58	0.564	-.0524299	.0960806
ADOPFERTBARL	-.014697	.0400986	-0.37	0.714	-.0934092	.0640152
ADOPCOMPBARL	.0316765	.0351025	0.90	0.367	-.0372286	.1005816
ADOPWEEDCIDE	.0657097	.03583	1.83	0.067*	-.0046234	.1360428
ADOPFREQPLOW	-.1397503	.0459877	-3.04	0.002***	-.2300227	-.0494779
ADOPFRQWEDING	.2010591	.0382549	5.26	0.000***	.1259659	.2761522
ADOPIMPBARSED	-.0645468	.0449796	-1.44	0.152	-.1528403	.0237468
ADOPFRMDRNAGE	.0109916	.0407155	0.27	0.787	-.0689316	.0909148
FORMCREDACES	-.1083316	.0404794	-2.68	0.008***	-.1877914	-.0288719
PARBELGPROD	.1231554	.0351405	3.50	0.000***	.0541758	.192135
LANDRENTINPART	.1029046	.0426514	2.41	0.016**	.0191812	.186628
BARSELOPTNS	.0618803	.0299025	2.07	0.039**	.0031825	.120578
PARTINBARLYVAD	-.0622075	.0552739	-1.13	0.261	-.1707085	.0462934
HHACESBARLEXT	.0855853	.0395217	2.17	0.031**	.0080056	.1631651
_cons	10.48806	.3265823	32.11	0.000	9.846985	11.12913

Source	SS	df	MS		
Model	189.980503	20	9.49902517	Number of obs =	812
Residual	159.427183	791	.201551432	F(20, 791) =	47.13
				Prob > F =	0.0000
Total	349.407686	811	.430835618	R-squared =	0.5437
				Adj R-squared =	0.5322
				Root MSE =	.44894

Source: own computation from 2014/2015HHs survey data
***, **, *, Represent, the 1%, 5%, 10% significant level respectively;

When the predictor, HHs' income in (Log Eth. Birr), increase by one unit (one Eth. Birr), the farm households' intensity of food availability showed to increase by 0.46 units (Log Kcal). The results of the analysis showed that livestock, farm land and income of the farm households are very crucial to enhance the intensity of farm households' aggregate food availability.

The effects of non-continuous predictors, as shown in Table 50, out of total twenty predictors, ten (10) were non-continuous, out of which, seven (7) affected the dependent variable, farm households' intensity of food availability in Log Kcal significantly, which include (weedicide adoption, frequent hand weeding adoption, farm HHs' access to formal credit service, participation in *Belg* production, participation in land rent-in participation, participation in barley selling options, farm HHs' access to barley extension service). Among which, households' formal credit service access, was affecting the dependent variable negatively, while the rest six (6) predictors were affecting the dependent variable positively. Therefore, the predictor, households' access to formal credit service affected the dependent variable in that, when farm households have access to formal credit service, their intensity of food availability in (Log Kcal) showed to decrease by 0.11 units (Log Kcal), which may be due to high cost of the credit service, or due to inappropriate use of credit.

The other non-continuous predictors' effect on the dependent variable, the farm households' aggregate intensity of food availability (Log Kcal), as indicated in the Table 50, when the farm households adopt weedicide, their intensity of aggregate food availability (Log Kcal), showed to increase by 0.066 units (Log Kcal). When the farm households adopt frequent hand weeding, the farm households' intensity of aggregate food availability in (Log Kcal) showed to increase by 0.20 units (Log Kcal). Furthermore, when the farm households participated in *Belg* production, the intensity of their food availability in (Log Kcal), showed to increase by 0.12 units (Log Kcal). As the farm households participated in land rent-in practice, the intensity of their aggregate food availability in (Log Kcal) showed to increase by 0.103 units (Log Kcal).

When farm households' participated in barley selling options, the intensity of their aggregate food availability in (Log Kcal) showed to increase by 0.062 units (Log Kcal). This finding is in consistence with the finding of Dowd-Uribe, et. al., (2015) that physical access to farmers' markets plays a crucial role in food security especially among low income households. Those households which do not live within close proximity to farmers' markets may miss out on what is the preferred and lowest cost option to access fruits and vegetables in Costa Rica. When the farm households accessed to barley extension service, the intensity of their aggregate food availability in (Log Kcal) showed to increase by 0.062 units (Log Kcal).

6.4. Determinants of barley food availability (Kcal) at farm household level

Barley (Hordeum vulgare L.) is one of the most important cereal crops in the world. It is widely grown fourth cereal and among top ten crop plants in the world (Akar, *et. al.*, 2004); and it is widely adapted, drought, salt, and cold tolerant cereal grain. Ethiopia is the second largest barley producer in Africa (FAO, 2014). Barley is the fifth most important cereal crop in Ethiopia after *teff*, maize, sorghum, and wheat (CSA, 2001). In Ethiopia, barley gets its name *Gebs Ye-ehil Nigus*", which to mean that barley is the king of crops due to its wide range of uses and suitability for preparing many of the known traditional dishes and beverages of Ethiopians (Shewayrga and Sopade, 2011).

In addition, barley in the study area produced widely for human consumption, for sell to get income, and for their livestock feed (straw). It is also used by the farm households for roof thatching and for mud plastering of the house wall. However, the focus, in this section of the study is to identify those determinants affecting the farm households' intensity of food availability from barley. To identify those determinants affecting the intensity of barley food availability from barley in (Kcal), first selection of explanatory variables was conducted, followed by variable description (given in the methodology section of this study). Following selection and variable description (which presented in the methodology section of this study), test for the existence of multi-Collinearity problem was conducted both for the continuous and non-continuous explanatory variables.

The model selected for this analysis is Censored Tobit regression model, and its' description was given in the methodology section of this study. As the variable inflation factor showed that the predictors farm HHs' mean perception towards agricultural extension service and market distance showed multicollinearity problem. Hence, rejected/discarded to be included in censored Tobit model for further analysis. The multi-Collinearity problem test result for continuous predictors, which is the variable inflation factor (VIF) test result has indicated in the Table 73. Furthermore, the multicollinearity test using correlation matrix was conducted for non-continuous predictors and the test result has shown in the Table 74. The correlation matrix result showed that there is no multicollinearity problem among the non-continuous predictors variables. Therefore, all the selected non-continuous explanatory variables were included in the Tobit regression model for further analysis.

The dependent variable used in this analysis is farm households' food availability intensity from barley in (Kcal), which is a continuous variable. The independent variables used in this analysis include continuous and non-continuous predictors that were included in the Tobit regression model after checking the existence of multicollinearity problem. The continuous predictors were six (6), which include, age, formal education in year, farm land, household size, household size in adult equivalent, livestock size, and households' annual income).The non-continuous predictors on the other hand are fourteen (14) that include (HH sex, fertilizer, compost, weedicide, frequent plow, frequent weeding, improved barley seed, farm land drainage adoption, formal credit access, household participation in barley selling option, participation in *Belg* production, participation in land rent-in, access to barley extension and rain-fed crop support with irrigation, support.

In this analysis, among the twenty (20) predictors, included in Tobit regression model, three (3) continuous, and nine (9) non-continuous predictors were showed significant effect on the dependent variable. Among these significant predictors, the three (3) continuous significant predictors were affect the dependent variable positively, and among those nine significant non-continuous predictors, three (3) were affecting the dependent variable negatively that include (weedicide, frequent plow and improved barley seed adoption), while the rest 6 (six) non-continuous significant predictors were affect the dependent variable positively as indicated in the Table 51. The effects of the predictors on the dependent variable are summarized in Table 51. As a result, the farm land size affected the dependent variable, the intensity of food availability from barley (Kcal) positively and significantly, as was presumed, with 5% significant level.

As it is indicated in the Table 51, when the farm land ownership of the farm households increases by one unit (one Ha), their intensity of food availability from barley showed to increase by 3.4% probability level among the total (812) sample households, by 336960 (Kcal) among the total (812) sample households, and by 262017 (Kcal) among the uncensored (803) sample households. The predictor, farm households' livestock size (TLU) and the dependent variable, the farm households' intensity of food availability from barley (Kcal) correlated positively and significantly, as was presumed with 1% significant level. The effect of the predictor, livestock size (TLU), showed that, when the households' livestock size increase by one unit (one Ha), the dependent variable, the farm households' intensity of food availability from barley (Kcal), showed to change by 0.7% probability level among the total (812) sample households, by 65878.56 (Kcal) among the total (812) sample households, and 51226.68 (Kcal) among uncensored (803) sample households, as indicated in Table 51.

The predictor, household' annual income in Eth. Birr and the dependent variable, the intensity of farm households' food availability in Kcal from barley correlated positively and significantly, with 1% significant level. The effect of the predictor, household' aggregate annual income in Eth. Birr on the dependent variable showed that, when the predictor, farm household' annual available income in Eth. Birr increase by 2%, their intensity of food availability from barley in (Kcal) showed to increase by 58 % probability level among the total (812) sample households, by 40 (Kcal) among the total (812) sample households and by 31(Kcal) among uncensored (803) sample households.

The censored Tobit regression result on the effect of farm land size, livestock ownership, and households' annual income on the dependent variable, households' food availability intensity from barley in (Kcal), revealed that these resources are very important to increase the intensity of farm households' food availability from barley in (Kcal). Off-farm income (as income proxy), this study finding is in line with Holden, et. al., (2004) that found off farm activity showed positive effect on welfare implications. Furthermore, this finding also agreed with the finding of Obiero (2013) that showed the positive and significant relationship between the farmers' income and the farm yield, which implies the households' food supply/availability improvement.

The coefficient of access to extension services is not statistically significant, but showed a positive relationship with food insecurity status of households. This implies that households with access to agricultural extension services tended to have less food insecurity than those that did not have such access and vice versa. This is because contact with extension services tends to enhance the chances of a household having access to better crop production techniques, improved inputs, as well as other production incentives that positively affect farm productivity and production and thus household food security status. The finding of this study has conformed with the finding of Obiero (2013). Furthermore, education and extension contact were positively and significantly correlated with annual gross income of crop farming system found in the study conducted by Sharma, *et. al*., (2007).

As a result, in this study, the non-continuous predictors' that include (fertilizer adoption, frequent plow and frequent weeding) adoption were correlated positively and significantly as presumed, with 10%, 1% and 5% significant level, respectively. These predictors affected the dependent variable, the intensity of farm households 'food availability (Kcal) to increase by some probability level. Hence, when the farm households adopted fertilizer, the intensity of their barley food availability, showed to increase by 3.22% of probability level, among the total (812) sample households, by 317024 (Kcal) among the total (803) sample households and by 24616 (Kcal) among the uncensored (812) sample households. The finding of this study on fertilizer adoption is in line with the findings of Haile, *et. al.*, (2005); Rahman (2011); Yengoh (2012) that fertilizer use has the potential to improve income from farming and to enable farmers to become less vulnerable to crop failures and food shortages.

Adoption of frequent weeding affected the dependent variable, intensity of food availability in (Kcal) from barley. When the farm households practiced/adopt frequent hand weeding of barley crop (two or more times weeding), their intensity of barley food availability in (Kcal) showed to increase by 4% probability level among total (812) sample households, by 397249 (Kcal) among the total (803) sample households, by 308898 (Kcal) among (812) uncensored sample households. This finding is agree with the finding of Yengoh (2012) that different agricultural practices (proxy variable for frequent weeding) such as farm residue, animal droppings, burning of plant remnants on farm can improve agricultural yields.

The effect of the predictor, sample farm households' participation in *Belg* production (small rainy season production), on the intensity of sample households' food availability in (Kcal) from barley showed to increase by 2.82% probability level among the total (812) sample households, by 277787 (Kcal) among the total (812) sample households, and by 216005 (Kcal) among the uncensored (803) sample households. It is supported by the study of Bogale and Shimelis (2009) that participation in irrigation production (the proxy variable for *Belg* production), showed statistically significant and negative effect on food insecurity, which means positive and significant effect to enhance farm households' food security.

Table 51. Censored Tobit regression model analysis output on determinants affecting respondents' intensity of barley food availability (Kcal)

Explanatory Variables	Coef.	Std. Err.	t	P>|t|	Marginal effect		
					Probability of change among total (812) sample HHs	Among total (812) sample HHs	Among (803) uncensored sample HHs
AGEHHHEAD	-4801.057	6128.515	-0.78	0.434	-.0004308	-3301.56	-4245.873
HHHFORMEDUYR	-49664.85	33867.25	-1.47	0.143	-.0044567	-34153.2	-43921.71
FARMLANDSIZEHA	381019.9	164836.1	2.31	0.021**	.0341912	262017.3	336959.6
HHSIZEADEQV	42192.84	51541.49	0.82	0.413	.0037862	29014.89	37313.75
LIVSTOCKIZETLU	74492.74	24567.15	3.03	0.003***	.0066847	51226.68	65878.56
ANAVINCOMEBIRR	44.7526	7.083268	6.32	0.000***	4.02e-06	30.77518	39.57751
HHHEADSEX	-192846.8	184197.9	-1.05	0.295	-.0173053	-132615.7	-170546.4
HHADOPFERTBARL	358477.5	194812.3	1.84	0.066*	.0321683	246515.5	317023.9
HHADOPCOMPBARL	43947.91	170562.4	0.26	0.797	.0039437	30221.81	38865.86
HHADOPWEEDCIDE	-482109.9	173886.7	-2.77	0.006***	-.0432626	-331534.2	-426359.7
HHADOPFREQPLOW	-680163.4	221643.4	-3.07	0.002***	-.0610352	-467730.3	-601510.8
HHADOPFRQWEDING	449193	185231.5	2.43	0.016**	.0403088	308898.1	397249.3
HHADOPIMPBARSEED	-400047.8	218248.5	-1.83	0.067*	-.0358987	-275102.2	-353787.1
HHADOPFRMDRNAGE	-182954.2	195344	-0.94	0.349	-.0164176	-125812.8	-161797.8
HHFORMCREDACES	-223746.6	194790.6	-1.15	0.251	-.0200781	-153864.6	-197873
HHACESBARLEXT	284076.8	191316.5	1.48	0.138	.0254919	195352.1	251226.8
BARSELOPTNS	314110.2	94606.37	3.32	0.001***	.028187	216005.2	277787.1
HHPARBELGPROD	388129.1	166818.5	2.33	0.020**	.0348292	266906.1	343246.7
LANDRENTINPART	529901.4	212363.2	2.50	0.013**	.0475512	364399.1	468624.7
RAIFEDCROPSUPIRG	730192.2	329648.4	2.22	0.027**	.0655245	502133.8	645754.3
_cons	917971.8	406769.3	2.26	0.024			
/sigma	2171560	54280.38					
Observation Summary	9, left-censored observations			Tobit regression	Number of obs.		812
	803, uncensored observations				LR chi2(20)		216.93
					Prob > chi2		0.0000
					Pseudo R2		0.0084
	0, right-censored observations				Log likelihood		-12865.11

Source: own computation from 2014/2015 HHs survey data; and ***, **, * represent 1%, 5%, 10% significant level respectively;

Furthermore, when the farm households participated in barley selling options, their intensity of food availability in (Kcal) from barley showed to increase by 2.55% probability level, among the total (812) sample households, by 251227 (Kcal) among the total (803) sample households, by 195352 (Kcal) among the uncensored (812) sample households. According to Tigist (2017), markets open opportunity to farm HHs to sell their outputs, which help them to buy & use improved inputs & to tap public and private services such as extension and credit access, which all help farm households to remain economically self-sufficient and maintain food security, which showed that market participation is vital for the farm households to be sufficient in their income and food availability. The market distance, a proxy variable for barley selling options, showed the negative effect on farm households' income status (Agbola, *et. al.,* 2010), which suggests that the farther a market is a farm lower the farm income accruable to farming households.

The predictor, sample farm households' participation in rain-fed crop support with irrigation, showed to increase the dependent variable, the intensity of farm households' food availability from barley in (Kcal), in that, when the farm households participated in supporting the rain fed barley crop with irrigation, their intensity of food availability from barley in (Kcal) showed to increase by 6.55% probability level, among the total (812) sample households, by 645754 (Kcal) among the total (812) sample households, and by 502134 (Kcal) among the uncensored (803) sample households. Participation in irrigation production and adoption of improved seed varieties correlated positively in the study of Beyan (2016), which is a proxy to enhance production and improve households' food security.

The predictor, participation of sample farm households' in farm land rent-in, affected the dependent variable, the intensity of farm households' food availability in (Kcal) from barley, in that, when the farm households' participated in rain fed crop support with irrigation, their intensity of barley food availability in (Kcal) showed to increase by 3.5% probability level among the total (812) sample households, 343247(kcal), among the total (803) sample households, and 266906 (Kcal)among uncensored (812) sample households. As shown in the aforementioned analysis that, the predictors' positive affect the dependent variable, the intensity of farm households food availability in (Kcal) revealed that the importance of those predictors to increase/enhance farm households' food availability from barley. This finding is in line with the finding of Muraoka, *et. al.,* (2014), who concluded that land rent-in play a positive and significant role in promoting household food security in rural Kenya.

Regarding the effect of adoption of weedicide on barley crop and farm households' intensity of food availability from barley (Kcal) showed negative and significant association, which is different from presumed. As a result, when farm households adopted weedicide, their intensity of food availability from barley in (Kcal), showed to decrease by 4.33% probability level among the total (812) sample households, by 331534 (Kcal) among the total (812) sample households, and by 426360 (kcal) among (803) uncensored sample households. The finding of this study showed inconsistence with the finding of Winters, *et. al.,* (1998), who concluded that farm households who adopt weedicide showed better in their food security.

The predictor, adoption of improved barley seed, in this study showed negative and significant effect on the farm households' intensity of food availability from barley in (Kcal). As a result, when the farm households adopt improved barley seed, their intensity of food availability from barley in (Kcal) showed to decrease by 3.6% probability level, among the total (812) sample households, by 353787 (Kcal) among the total (812) sample households, and by 275102 (Kcal) among the uncensored (812) sample households. In the study of Beyan (2016);Yengoh (2012), adoption of improved seed adoption showed positive relationship, which implied to increase yield and thereby food availability. However, in this study improved seed adoption affected food availability from barley negatively, which could be due to poor resistance and adaptation of the improved barley seed to environmental situation.

The predictors, farm households' participation in barley selling options, in *Belg* production, in rain fed crop support with irrigation, and in land rent-in were correlated with dependent variable, intensity of farm households' food availability (Kcal) from barley positively and significantly, at 1%, 5%, 5% and 5% significance level, respectively. The predictors' affected the dependent variable, to increase by some amount of food (Kcal) and probability level as indicated in the Table 52. On the other hand, the predictor, farm households' participation in frequent barley farm land plowing (three or more times of plowing), affected the dependent variable, in that, when the farm households adopt/participate in frequent plowing of barley farm land, their intensity of food availability in (Kcal) from barley decreased by 6% probability level, among total (812) sample households, by 467730 (Kcal) among total (812) sample households, and by 601511 (Kcal) among uncensored (803) sample households. The finding of this study showed inconsistence with the finding of Irz, *et. al.,* (2001).

CHAPTER SEVEN: DETERMINANTS OF FARM HOUSEHOLDS' PERCEPTION TOWARDS EXTENSION SERVICE AND ITS CONTRIBUTION IN BARLEY TECHNOLOGIES ADOPTION, INCOME AND FOOD AVAILABILITY

7.1. Concept and measurement approaches of perception

Perception, which also known as social perception to mean constructing and understanding of the social world using sensory data; and it is the process by which humans form impressions of other people's traits and personalities. Perception acts as filter through which new observations are interpreted. It is the process by which human beings/individuals received information or stimuli for environment and transform it into psychological awareness. It is the process that encompasses the senses and enables a person to reach at true beliefs about their environment. Furthermore, perception can be defined as beliefs/opinions held by many people based on how things seem to them. Knowledge, on the other hand, concerns the way people understand the world, and how they interpret and apply meanings to their experiences (Blaikie, *et. al*, 1997; Van de Ban and Hawkin, 1988).

Perception and knowledge guided decision making and consequently human's action (Kisauzi, *et. al*, 2012). Therefore, perception is sensory based information individuals try to understand their surroundings and reach conclusion and decision. The human behavior that include (attitude, character and personality) is difficult to measure due to its subjective nature (Subedi, 2016). The measurement of characteristics related to human perception deserves great attention for both scientific and practical reasons. From the scientific standpoint, they are essential for the understanding of human perception, which in turn is basic for the study of (attentional, cognitive and emotional) functions. From the practical side, such measurements (human perception characteristics) are inherently appealing, since they are customer oriented, highly informative and provide direct information on the perceived quality of products, devices, services, and the environment (Rossi and Berglund, 2009).

There are four standard measurement scales (nominal, ordinal, interval and ratio) to use as a base to develop survey. Which one to apply depends on the information type contained in the measurement results. So, addressing the most suitable one is crucial and enhances the success of measurement analysis (Xenos and Christodoulakis, 1995 and 1997). Among the four measurement scales/types, the nominal scale is used for labeling variables (without quantifying them) that can have two or more non-ordered categories. Nominal scale with only two categories (male/female) is dichotomous; but, with more than two, it is called as categories, like brown, black, grey color (Subedi, 2016). Nominal scale measurements represent the most unrestricted assignment of numerals and used only as labels or type numbers. For instance, the use of numerals as names for classes, which is the assignment of numerals according to rule that says, “don’t assign the same numeral to different classes” (Stevens, 1946).

The second and third measurement scales are the ordinal and the interval scales, respectively. The ordinal scales measurement arranges or ranks things. In this type of scale, according to Stevens (1946), the numbers assigned to objects or events to represent the rank order, for example, hardness of minerals, and scales of intelligence or quality of leather. Regarding the interval scale, the third measurement scale, shows the order of things, although equal intervals between points on the scale is essential. Quantitative attributes are all measurable on interval scales. It is about the data points order and size of the intervals in between data points. The fourth measurement scale is the ratio scale measurement, which is differs from interval scale in that it has zero value and points along the scale make sense as ratios.

Most measurements in the physical sciences and engineering are done using ratio scales, which are of two types that include the fundamental and the derived ratio scales. The fundamental scales are represented by (length, weight and electrical resistance); while the derived are represented by (density, force and elasticity). The ratio scale type takes its name from the fact that measurement is the estimation of ratio between magnitude of continuous quantity and a unit magnitude of the same kind. Numerous methods can be used to measure human behavior (attitude, character and personality traits) numerically (Likert, 1932). The need to quantify human behavior lies to transform individual's subjectivity into objective reality (Joshi, *et.al.,*2015). Likert introduced the summative method in (1932); and consequently, the tool is called as Likert scale, which currently used widely to collect likert scale data (Boone, 2012).

Likert scales have been developed to measure attitudes by asking people to respond to a series of statements/questions about a topic, in terms of the extent to which they agree. Hence, Likert scale data assumes that the strength/intensity of experience is linear (on a continuum from strongly agree to strongly disagree). In this regard, respondents may be offered a choice among pre-coded responses with the neutral point being (neither agree nor disagree). These types of responses have not merely categories, but also ordered. Therefore, Likert type data cannot be treated as nominal and as ratio level. Hence, it unusual and not correct to treat Likert type data as nominal and ratio levels, since Likert scale cannot entertain the nominal and ratio level data (Brown, 2011).

Social scientists used qualitative methods to explore human subjectivity through follow up ideas, probe responses, and investigate motives and feelings. They also want to quantify human behavior (attitudes, characters and personality traits), according to Wing and Cheng (2000). Currently, the widely used method to collect the survey data is using statements/ items/questions with response categories. The Original Likert Scale data can be used a series of questions with alternative responses that include (for example, from strongly approve to strongly disapprove), which can be combined to create summative (aggregate) attitudinal measurement scale. Likert type data are discrete, but not continuous that tied numbers, and restricted ranges (Jamieson, 2004).

In the Likert scale, data collection method design, analysis and interpretation of the result, are necessary to determine in advance clearly the difference between the (Likert items, and Likert scale) through close evaluation of characteristics of items/statements such as their arrangements in logical sequence; and their close interrelationship; if they provide independent information; the elements of coherences; and whether each item measures a distinct element of the issue. Therefore, the attitude and behavior of the participants through mutually exclusive items which are known as the Likert Items that can be captured through individual Likert data analysis. Hence, these items can't combine to form a scale. It is necessary to analyze them separately. Multiple questions may be used in a research instrument, but there should not be attempted by the researcher to combine the responses from the items into a composite scale (Joshi, *et. al*, 2015).

On the other hand, in the Likert scale, opinions/perceptions of participants in a (specific construct) can be collected; and the numbers of items/statements/questions related to a (particular construct) are prepared. Then, during the analysis the score of the entire items of a construct is combined to generate composite score (Subedi, 2016). In addition, items in logical sequence, closely interrelated elements in coherence, and each item has the capacity to measures a distinct element of issue. Due to these characteristics, items can be combined to construct composite index that measures collective stance of participants towards phenomenon under study (Joshi, et al, 2015). Therefore, the combined Likert scales/items, are used to provide a quantitative measure or personality trait (Boone and Boone, 2012).

In using Likert type data, it is necessary to clarify whether midpoint is used or not, since there is a disagreement among researchers regarding the midpoint's effect on the reliability and validity of measurements (Subedi, 2017). The supporters of midpoint opinions claim that the midpoints can increase reliability, while the opponents claim that midpoints cannot increase measurement reliability (Tasang, 2012). Furthermore, some studies found that construct validity may not be influenced by midpoints (Adelson and McCoach, 2010), while others like Johns (2005), keeping out midpoints may weaken validity. From the methodological point of view, both use and not use of midpoints are acceptable since midpoints may not affect reliability and validity. From epistemological point of view midpoint is necessary and need attention in designing the Likert scale measurement with midpoints (Tasang, 2012). The mid points may be viewed by respondents as a "dumping ground" for unsure or non-applicable responses. The meanings of "midpoint" are multiple that include (neutral, undecided, don't know, or neither agree nor disagree), hence, it is important to clearly show what meaning it has and what place it represents in the Likert scale items (Subedi, *et. al.*, 2017).

Regarding the analytical methods, both descriptive and inferential statistics were employed. Among descriptive statistics, frequency, percentage, mean, standard deviation was employed. Furthermore, according to Hosmer and Lemeshow (2000), Ordered Legit/Probit model can be used to analyze Likert scale data having ordinal structure of the dependent variable that need to have at least three categories, like for example, severity of disease (mild, moderate, severe), level of education (elementary, high school, university). Therefore, in the current study, data from respondents were collected using nine (9) interrelated Likert scale questions (statements) with five response categories. Then, the response of respondents for the nine Likert items, the mean and level of perception were estimated; and the sample households' distribution based on their food availability, income perception level were conducted. Furthermore, the determinants of farm households' mean and level of perception using Censored Tobit regression model and ordered logit regression model were also conducted.

7.2. Farm households' perception towards agricultural extension service

Perception, as defined by Shaver in Johnson (1994), it is an understanding of the world constructed from information obtained by means of the senses. In this study, the perception of farm households towards the role of agricultural extension in enhancing improved agricultural technologies, income and food availability. As a result, data on farm households' perception towards agricultural extension service for this study were collected using nine questions/statements, each statement with five response categories /scales. Respondents were expected to choose one option among available options given for each statement/item. Then, the sample households' responses were analyzed using frequency, percentage and mean. In this analysis, when the sample households' mean response to the nine Likert scale questions/items is below (3), they considered as households with low perception represented by (1); if it is equal to (3), they considered as households with medium perception represented by (2); and if it is greater than (3), they considered as households with high perception represented by (3).

The sample households' perception towards agricultural extension was analyzed and summarized in the Table 52, using frequency and percentage. As a result, the summary of sample households' perception based on their response for the nine questions based on the five response categories that, out of the total (812) sample households those choose strongly disagree were (6.17%), those who respond disagree (17.15%), those who choose undecided were (17.41%), those who choose agree were (46.74%), and those who choose strongly agree were (12.53%). Out of which the majority of sample households choose category, agree (46%), which revealed that the majority of farm households accept the extension service is vital for the farm community to adopt improved agricultural technologies, thereby, to improve their income and food availability. From individual mean perception, the overall sample farm households are (3.42). The mean perception of sample households towards agricultural extension service (3.42), which showed that the majority of the sample farm household showed high and positive perception towards agricultural extension service. Farm households with positive and higher level of perception towards agricultural extension may use improved technologies and information relevant to enhance their agricultural production and productivity. Farm households with better level of perception to extension might have better knowledge and skill how to use and importance of improved agricultural technologies.

Table 52. Sample households' responses to Likert scale statements on agricultural extension service as regard to barley technologies adoption

Likert scale Questions/items	Respondents' distribution based on their response to the likert scale items and categories							Total agreement/812 respondents = Mean Perception for each item/ statement
	SDA(1)	DA (2)	Undecided (3)	AG (4)	SAG (5)	Total	Average	
Q1. The extension service is weak to improve farmers skill/knowledge	49 (6%)	157 (19.30%)	107 (13.20%)	374 (46.10%)	125 (15.40%)	812 (100%)	812/5= 162.40	3.45
Q2. Extension service is unable to improve yield/income/food supply	53 (6.53%)	174 (21.43%)	120 (14.78%)	381 (46.92%)	84 (10.34%)	812 (100%)	812/5= 162.40	3.33
Q3. Training on improved technologies for farm HHs is important	31 (3.82%)	109 (13.42%)	93 (11.45%)	461 (56.77%)	118 (14.53%)	812 (100%)	812/5= 162.40	3.65
Q4. DAs not give adequate time to advice farm HHs	47 (5.80%)	142 (17.50%)	132 (16.26%)	395 (48.65%)	96 (11.82%)	812 (100%)	812/5= 162.40	3.43
Q5. In extension advice farm HHs' interest not considered	37 (4.56%)	150 (18.47%)	154 (18.97%)	388 (47.78%)	83 (10.22%)	812 (100%)	812/5= 162.40	3.41
Q6. Organizational structure of extension not strongly organized	53 (6.53%)	125 (15.40%)	202 (24.88%)	357 (43.97%)	75 (9.24%)	812 (100%)	812/5= 162.40	3.34
Q7. Extension professionals competency is not adequate	48 (5.91%)	91 (11.21%)	189 (23.28%)	354 (43.60%)	130 (16.01%)	812 (100%)	812/5= 162.40	3.53
Q8. The office of agricultural extension is far to reach and get timely advice	70 (8.62%)	123 (15.15%)	158 (19.46%)	347 (42.73%)	114 (14.04%)	812 (812%)	812/5= 162.40	3.38
Q9. Extension not give for timely activities	63 (7.76%)	182 (22.41%)	117 (14.41%)	359 (44.21%)	91 (11.21%)	812 (100%)	812/5= 162.40	3.30
Number and percent of respondents for the nine items	451/7308 *100 = (6.17%)	1253/7308*100= (17.15%)	1272/7308*100= (17.41%)	3416/7308*100= (46.74%)	916/7308*100 = (12.53%)	7308/7308*100= (100%)	1461.6/9 = 162.4	3.42 (mean of means)
Average respondents response on each likert question by category	50.11 (6.17%)	139.22 (17.15%)	141.33 (17.41%)	379.56 (46.74%)	101.78 (12.53%)	812 (100%)	812/5= 162.40	

Source: own computation from 2014/2015 household survey data; *SDA (Strongly Disagree), DA (Disagree), MA (Moderately Agree), AG (Agree), SAG (Strongly Agree)

Hence, the higher and positive perception of farm households towards agricultural extension plaid a significant role to enhance their income and food availability (food supply) by improving their agricultural production through use of improved technologies and information they get from extension service. Furthermore, the sample households' distribution by the study *woreda,* by gender and by sample households' perception level has summarized in Table 53. As a result, out of the total (812) sample households 196 (24.14%) were with low perception, 53 (6.53%) were with medium perception level and 563 (69.33%) were with high perception level. Similarly, the male and female sample households' distribution by perception level has also summarized in the Table 52, in that, out of the total (604) male sample households, (21.17%), were with low perception, (7.45%) were with medium and (67.38%) were with high perception level.

Table 53. The sample households' perception towards agricultural extension

HHs' perception Distribution	Farm HHs' Perception level towards extension service			**Total sample HHs**
	Low	Medium	High	
Ankober	127 (47.04)	17 (6.30)	126 (46.67)	270
Basona	8 (2.94)	29 (10.66)	235 (86.40)	272
Angolela	61 (22.60)	7 (2.60)	202 (74.80)	270
Total	196 (24.14)	53 (6.53)	563 (69.33)	812
Male	152 (21.17)	45 (7.45)	407 (67.38)	604
Female	44 (21.15)	8 (3.85)	156 (75)	208
Total	196 (24.14)	53 (6.53)	563 (69.33)	812
Adopters	169 (22.90)	43 (5.83)	526 (71.27)	738
Non-adopters	27 (36.49)	10 (13.51	37 (50)	74
Total	196 (24.14)	53 (6.53)	563 (69.33%)	812
Below minimum Kcal (2550)	75 (26.80)	22 (7.86)	183 (65.36)	280
Equal/above (2550Kcal)	121 (22.74)	31 (5.83)	380 (71.43)	532
Total	196 (24.14)	53 (6.53)	563 (69.33)	812
Below minimum (3781 Eth. Birr)	113 (27.30)	27 (6.52)	274 (66.18)	414
Equal/above (3781 Eth. Birr) income	83 (20.86)	26 (6.53)	289 (72.61)	398
Total	196 (24.14)	53 (6.53)	563 (69.33)	**812**
Total respondents' perception	**270 (33.25)**	**272 (33.50)**	**270 (33.25)**	

Source: computed from own Household Survey (2014/2015); and numbers in parenthesis represent percent

The female sample households with low perception (21.15%), with medium (3.85%), and with high perception (75%). In both male and female sample households, the highest proportion were with high perception towards agricultural extension service is relevant in barley technologies adoption thereby to enhance farm households' income and food availability. The sample households' distribution in this study has summarized in Table 53 by *woreda,* and by their perception. As a result, in *Ankober woreda*, out of the total (270) sample households, (47.04%) were with low perception, (6.30%) were with medium perception, and (46.67%) were with high perception towards agricultural extension service. In *Basona woreda*, out of the total (272) sample households in the *woreda,* (2.94%) were with low perception, (10.66%) were with medium perception, and (86.40%) were with high perception towards agricultural extension service. In *Angollela woreda*, one of the study *woreda* for this study, out of the total (270) sample households, (22.60%) were with low perception, 2.60%) were with medium perception and (74.80%) were with high perception. In all the three study *woredas* the higher proportion of sample households were with high perception level. However, in the *Ankober woreda*, the proportion of the sample households with low perception and high perception are almost equal.

The sample households' distribution by their food availability status and perception level, as shown in Table 53 is that, among the total (280) sample households with food availability status below the minimum requirement (2550 Kcal) per person per adult equivalent, according to CSA and WFP (2014), (26.80%) were with low perception, (7.86%) were with medium perception and (65.36%) were with high perception. On the other hand, out of (532) sample households with food availability status in (Kcal) that, households with equal/above the minimum requirement, (22.74%) were with low perception, (5.83%) with medium, (71.43%) were with high perception towards agricultural extension service. Among the sample households with food availability status equal and above, the highest proportion of them were with high perception level.

Furthermore, the sample households with income status below and equal or above the minimum requirement (Eth. Birr. 3781), according to CSA and WFP (2014), has summarized in the Table 53. As a result, among the total (414) sample households with income below the minimum, (27.30%) were with low perception, (6.52%) were with medium perception and (66.18%) were with high perception level. On the other hand, out of the total (398) sample households with income status equal/above the minimum income standard (Eth. Birr 3781), (20.86%) were with low perception, (6.53%) were with medium perception and (72.61%) were with high perception, which revealed that the majority of the sample households with equal and above the minimum income status, the highest proportion were with high perception level.

The sample households' distribution by improved barley technologies adoption and by their perception towards agricultural extension service has summarized in the Table 53. As a result, out of the total (738) adopters, (22.90%) were with low perception, (5.83%) were with medium perception and (71.27%) were with high perception level. Regarding the non-adopters, out of the total (74) non-adopters of barley technologies, (36.49%) were with low perception, (13.51%) were with medium perception level and (50%) were with high perception level. In both cases (adopters and non-adopters the higher proportion of sample households were with high perception level. Hence, the majority of sample households in the study area have higher perception towards agricultural extension service.

7.3. The contribution of farm households' perception towards adoption of barley technologies, income and food availability of households

The farm sample households with better perception are expected to adopt improved agricultural technologies, thereby, they can improve their income and food supply/food availability. As the two sample t-test analysis result showed in the Table 54.

Table 54.Two sample t-test and intensity of perception in adoption of barley technologies

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Non-adop	74	3.046547	.0784366	.6747372	2.890223	3.20287
Adopters	738	3.461006	.0240657	.6537725	3.41376	3.508251
combined	812	3.423235	.0233743	.666066	3.377353	3.469116
diff		-.4144592	.0799525		-.5713977	-.2575206

diff = mean(Non-adop) - mean(Adopters) t = -5.1838
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.0000 Pr(|T| > |t|) = 0.0000 Pr(T > t) = 1.0000

Source: own computation from household survey 2014/2015

The mean perception of improved barley technologies adopters was higher by the units of 0.41 mean perception as compared to the non-adopters. Hence, the two sample t-test analysis result showed that the farm households with higher perception towards agricultural extension service are better in adoption of improved barley technologies than those with lower perception towards agricultural extension service. In this study, the farm households' perception towards agricultural extension service, was expected to enhance the income of farm households. Furthermore, as indicated in the Table 55, the two sample t-test analysis showed that farm households with income equal and above the minimum income standard showed higher mean perception intensity by 0.09 towards agricultural extension service than households mean perception intensity towards agricultural extension service.

Table 55. Two sample t-test and the contribution of extension perception on households' income

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
HHs belo	414	3.37869	.0337249	.6861996	3.312396	3.444984
HHs equa	398	3.46957	.0321826	.6420409	3.4063	3.53284
combined	812	3.423235	.0233743	.666066	3.377353	3.469116
diff		-.0908798	.0466775		-.1825029	.0007433

```
    diff = mean(HHs belo) - mean(HHs equa)                        t =  -1.9470
Ho: diff = 0                                     degrees of freedom =      810

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0259         Pr(|T| > |t|) = 0.0519          Pr(T > t) = 0.9741
```

Source: own computation from household survey 2014/2015

Therefore, the higher perception of farm households, they have developed towards the importance of extension service help them to improve their income status from lower level to equal and above the minimum income status as indicated in Table 55. The perception of farm households' also important to enhance their food availability status. As the two sample t-test analysis result showed in the Table 56, the perception of farm households with food availability status equal and above the minimum standard showed higher mean perception by 0.022 units than those farm households with food availability status below the minimum food availability status. Hence, the higher level of perception towards agricultural extension help farm households to enhance farm their food availability status, which could be due to the fact that farm households with higher level of perception towards agricultural extension service may use information and improved technologies to improve their production, thereby, their food availability status and wellbeing.

Table 56. Two sample t-test on farmers' extension perception and food availability

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Food ins	280	3.409127	.041873	.7006698	3.3267	3.491554
Food sec	532	3.43066	.0280798	.6476648	3.375499	3.485821
combined	812	3.423235	.0233743	.666066	3.377353	3.469116
diff		-.021533	.0492014		-.1181102	.0750442

diff = mean(Food ins) - mean(Food sec) t = -0.4377
Ho: diff = 0 degrees of freedom = 810

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 0.3309 Pr(|T| > |t|) = 0.6618 Pr(T > t) = 0.6691

Source: own computation from household survey 2014/2015

Farm households with higher perception towards agricultural extension service showed better status in their adoption of improved barley technologies and improved practices, in their income, and in their food availability status as compared to those with lower perception towards agricultural extension service. Therefore, higher perception of farm households is critically important to improve farm households' adoption of improved technologies and improved practices, income and food availability statuses.

7.4. Determinants of farm households' perception level towards agricultural extension service (ordered logit regression model analysis)

The descriptions for the selected predictors were given in the Annex 1.1. section of this study. In addition, the model specification, regarding order logit model, and the dependent variable as well as the analytical model specification have been the research methodology chapter of this study. The dependent variable, in this study is, farm household' perception level towards agricultural extension service, which has three categories that include (low perception represented by 1, medium perception represented by 2, and high perception represented by 3). The independent variables were eight (8) continuous and non-continuous predictors were seven (7), a total of 15 predictors were used in this analysis. The continuous predictors include farmland size (Ha), household head age in (years), household Log livestock size in (TLU), Log credit center distance (Km), Log income (Eth. Birr), Log market distance (Km), Log DA office distance (Km).

In the analysis of determinants of farm households' perception level towards agricultural extension service, using ordered logit regression model, before including the predictors in the model, multicollinearity test problem were checked for continuous predictors using variable inflation factor (VIF), and correlation matrix for non-continuous predictors. The multicollinearity test results have summarized in the Table 75 (Annex) for continuous predictors and for the non-continuous predictors in Table 76 (Annex). In both multicollinearity tests, the results of the tests showed that there were no multicollinearity problem. Hence, all the selected (15) predictors were included in the ordered logit regression model for further analysis; and the result of the ordered logit regression model has been summarized in the Table 57.

To use ordered logit in this analysis, the suggestion of Chen and Hughes (2004a) was employed that described inferential statistics (regression) analysis, which can be used to determine the relationships between multiple predictors and dependent variables, which is the common practice in regression analysis. The regression models can also be used to describe the magnitude and direction of predictors' effects on dependent variable. When the response variable of interest is ordinal, ordered logit regression model can be used (Grilli and Rampichini, 2014). Often, dependent variables are ordinal, but are not continuous, in the sense that the metric used to code variables is meaningful (Jackman, 2000). Furthermore, ordered logit model, as discussed by Long (1997) was developed independently in the social sciences (in terms of an underlying latent variable with observed, ordered categories).

In this study, ordered *logit* regression model was employed since the dependent variable is ordinal with three categories that include (low, medium and high) perception of sample farm households towards agricultural extension service in the study area, *Semen Shewa*, *Amhara* region, Central Ethiopia, specifically in *Ankober, Basona* and *Angollela woredas*. As a result, when the changes in the individual ordered log-odds of falling into the high perception level versus to the medium and low perception levels in the respective predictor; the other variables in the model are held constant.

Table 57. Farmers' perception levels towards agricultural extension service (Ordered Logit)

Predictors	Coef.	Std. Err.	z	P>z	Marginal effect	
					Std. Err.	(dy/dx)
FARMLADSZHA	.4121976	.1289594	3.20	0.001***	.02239	.0712958
LOGAGEHHHEAD	.1275236	.5898514	0.22	0.829	.10202	.0220571
LOGHHHEDUCYR	.2410573	.237591	1.01	0.310	.04109	.0416945
LOGLIVSTOKTLU	-.5584777	.2026521	-2.76	0.006***	.0351	.0965972
LOGCRDCEDSKM	-.4900201	.2324433	-2.11	0.035**	.04024	.0847564
LOGINCOMEBIRR	.1737583	.2069974	0.84	0.401	.03581	.0300541
LOGMARKDISKM	.1480042	.1382315	1.07	0.284	.02391	.0255996
LOGDAOFICEKM	-.2210723	.1851156	-1.19	0.232	.03203	.0382378
SEXHHHEAD	-.1996418	.154776	-1.29	0.197	.02534	.0335962
PARTIMPLIVSPRD	.3414656	.1483113	2.30	0.021**	.02567	.0590617
FTCAVALABLITY	.4415532	.2543251	1.74	0.083*	.04405	.0763733
FODAVLSTATUS	-.1628961	.1625714	-1.00	0.316	.02733	.027779
INCOMESTATUS	.0122697	.1694904	0.07	0.942	.02931	.0021221
NBARTECHADOP	.1566363	.0649494	2.41	0.016**	.01125	.0270926
MONTHEXCONTF	.7605807	.1421471	5.35	0.000***	.02445	.131554
/cut1	.6738081	1.320056				
/cut2	2.909133	1.324215				
Number of obs.	812		Prob > chi2		0.0000	
LR chi2(15)	80.90		Pseudo R2		0.0472	
Log likelihood =-815.83808						

Source: Source: own computation from 2014/2015 HHs' survey data;
*, **, and *** represent the significance level of 10%,5% and 1% respectively;

Because of the dependent outcomes are ordered in to (low, medium, and high), a positive coefficient indicates an increase in the corresponding dependent variable, which is an increase in households' perception towards agricultural extension service. The opposite is true for negative coefficients. Regarding the odd ratios that indicate the number of times of chances for subjects in the perception category is multiplied when there is a unit change in the specific predictor. The cut1 and cut2 points are the estimated cut points on the latent variable used to differentiate the observed levels of perception when the values of the predictors are evaluated at zero. The odds ratio measures the proportional probability of farm households' perception to be (low, medium or high) for a unit increase or decrease in each explanatory variable.

As indicated in the Table 57, the ordered logit regression model analysis result showed that among 15 predictors that were hypothesized to affect the sample farm HHs' perception level towards agricultural extension service, 7 predictors showed significant effects on the dependent variable. Among those significant predictors, five predictors that include (farm land size, participation in improved livestock production, farmers' training center availability, number of barley technologies adopted, extension contact frequency) showed positive and significant correlation with the dependent variable (farm households perception level), as were hypothesize with 1%, 5%, 10% 5% and 1% significant level, respectively. The two predictors (livestock size and credit center distance) showed negative correlation with the dependent variable at 1% and 5% significant level, respectively. The credit center distance negative sign was as presumed, while the livestock size (TLU) negative sign was differently from what was presumed.

After checking the existence of multicollinearity problem for the predictors, they were included in ordered logit regression model to determine their effects on the perception of farm households' towards agricultural extension service offered in the study area. As indicated in the Table 57, the output showed that the predictors, livestock size in (TLU) and credit center distance in (Km) showed negative correlation with the dependent variable at 5% significance level. Regarding their marginal effects that, when the livestock size in (TLU) increased by one unit, the farm households' perception level decreased with 10% probability level to the lower level versus the high and medium perception levels. Regarding the credit center distance marginal effect, when the credit distance increased by one unit (one Km), the farm households' perception level decreased by 8.4% probability level to the lower perception level versus the high and medium perception levels. The findings of this study showed consistency with the findings of Osta and Morehart (1999), Caviglia-Harris (2002), Gbetibouo (2009).

The predictors farm land size, participation in improved livestock production, farmers' training center availability, number of barley technologies adopted by the farm households, frequency of extension contact affected the dependent variable, the farm households' perception level towards agricultural extension service as indicated in Table 57. As a result, when the farm land size in (Ha) increased by one unit (one Ha), the farm households' perception level increased by 7.13% of probability level versus the medium and lower perception levels of farm households towards agricultural extension service offered in the study area. This finding is different from the finding of Uddin, *et.al.,* (2017) who reached at conclusion regarding the farm households' perception towards climate change that farm households with larger farm land size showed low perception.

The positive effects of the four non-continuous predictors, (farm households' participation in improved livestock production, availability of farmers' training center, number of barley technologies adoption, and frequency of extension contacts) on the dependent variable (farm households' perception towards agricultural extension service offered in the study area as indicated in the Table 58, when the farm households were participated in each of these predictors, their perception level towards agricultural extension service offered in the study area increased by 6%, 8%, 3% and 13% probability level respectively viruses the medium and low perception levels. The findings of this study are in line with the findings of Maoba (2016), Muhammad and Chris (1999), Pervaiz (2009), Ahmad (1992), Sarker and Itohara (2009), Neupane *et al.,* (2002), Desalew and Aklilu, (2017) Adesina and Forson (1995), Gbetibouo (2009), Maddison (2006), Nhemachena and Hassan (2007), Wandji, *et. al.,* (2012), Herath and Wijekoon (2013), Prihtanti, (2016), Yusuf, *et. al.,* (2011).

7.5. Determinants of farm households' intensity of perception towards agricultural extension service (Censored Tobit)

In this study, to analyze farmer' perception intensity (mean perception) towards agricultural extension service, Censored Tobit Regression Model was employed. For this study, fourteen (14) explanatory variables were selected, and multicollinearity tests both for continuous and non-continuous predictors were conducted, before entering the predictors in the model. The multicollinearity test results showed that among the continuous predictors, household size showed multicollinearity problem and it was discarded from entering in the model and from further regression analysis. Then, for the final analysis, thirteen (13) predictors that include eight (8) continuous and five (5) non-continuous were taken. Description of the predictors and the dependent variable, as well as model specification (Censored Tobit regression model) were given in the methodology section (chapter) of this study. Furthermore, before including the predictors in the model for further analysis, multicollinearity tests for both continuous and non-continuous predictors were conducted and the results have summarized in Table 65 and 66 respectively.

The multicollinearity for continuous explanatory variables was conducted using the variable inflation factor (VIF); and the result of the test has summarized in 77. The VIF test result showed that household size in adult equivalent showed multicollinearity problem, then discarded not to be included in the Censored Tobit regression model and not to be used in further analysis. In addition, multicollinearity test for non-continuous predictors, correlation matrix analysis was conducted and the result of the test has summarized in Table 78. As the test result showed that there were no multicollinearity problems among the non-continuous predictors. Hence all the selected non-continuous predictors were included in the Censored Tobit regression model for further analysis. Furthermore, in this analysis, the continuous predictors that were included in the model, after checking for the existence of multicollinearity problem, were eight (8), which include household head age in years, education in years of schooling, livestock size in (TLU), farm land size (Ha), credit center distance (Km), income in Eth. Birr, market distance (Km), and DA-office distance in (Km); and the five (5) non-continuous predictors were (farm households' participation in barley value addition practices, household head sex, participation in improved livestock production, access to extension service, households' off-farm participation).

The effects of predictors summarized in the Table 58. As it is indicated in the Table 58, farm land size in (Ha) and sample farm household's intensity of perception towards agricultural extension service showed, positive correlation, as was presumed, with 1% significant level. The effect of farm land size on the dependent variable showed that when the farm land size increase by one unit (one Ha), its effect on the dependent variable, showed to increase by 4% probability level among the total (812) sample farm households, by 0.14 units among the total (812) sample farm households, and by 0.14 units among (807) uncensored farm households. The finding of this study is in line with the finding of Aklilu, *et. al.*, 2016 that farmland size farm households' perceptions on climate change factors (cool days and warm nights), the proxy variable for extension perception, showed a positive and significant correlation.

Table 58. Tobit regression model analysis outputs on farm households' (mean) intensity of perception determinants towards agricultural extension service (Censored Tobit)

HHs mean perception predictors	Coef.	P>t	Prob. Prediction (obs.=812)	Magnitude change (obs=812)	Magnitude change (obs=807)
FARMLADSZHA	.1425132	0.002***	9.04e-06	.142513	.1425132
AGEHHHEAD	.0006897	0.691	4.38e-08	.0006897	.0006897
HHHFORMEDUYR	.0108692	0.256	6.89e-07	.0108692	.0108692
MARKETDISTANCE	.0037713	0.192	2.39e-07	.0037713	.0037713
HHINCOMETHBIRR	3.48e-06	0.081*	2.20e-10	3.48e-06	3.48e-06
CREDCENTDISTKM	-.0095635	0.027**	-6.07e-07	-.0095635	-.0095635
LIVSTOCKSIZTLU	-.0078117	0.257	-4.96e-07	-.0078117	-.0078117
HHHOMDISDAOFKM	-.0066287	0.239	-4.20e-07	-.0066287	-.0066287
HHHEADSEX	-.0697443	0.182	-4.42e-06	-.0697442	-.0697443
HHACCESAGREXT	.213524	0.009***	.0000135	.2135237	.213524
HHPARIMPLIVPROD	.1576928	0.002***	.00001	.1576925	.1576927
HHOFFARMPART	.0969628	0.059*	6.15e-06	.0969626	.0969628
HHPARBARVADNS	-.0833492	0.039**	-5.29e-06	-.083349	-.0833492
_cons	3.147316	0.000			
/sigma	.6442369				

Tobit model summary	Observation summary	
3 right-censored observations at HH mean perception >=5	Number of obs	812
	LR chi2(13)	62.07
2 left-censored observations at HH mean perception<=1.44	Prob > chi2	0.0000
	Pseudo R2	0.0374
807 Uncensored observations	Log likelihood	-798.0272

Source: Own computation from 2014/2015 HHs' survey data;
The *, **, ***; represent 10%, 5% and 1% significant level respectively;

Regarding the effects of predictor, households' income in Eth. Birr, which affected the dependent variable, households' intensity of perception towards agricultural extension service, in that, when the farm households' income increase by one unit (one Birr), the dependent variable, sample farm households' intensity of perception, showed to increase by 20% probability level among the total (812) sample households, by 3.48 units (intensity of mean perception) among the total (812) sample households and by 3.48 units (intensity of mean perception among the (807) uncensored sample households as indicated in the Table 58. This finding is in line with the finding of Uddin, *et. al.*, (2017), Semenza *et al.* (2008) that family income and farmers' perception of climate change showed positive and significant relationship.

The credit center distance (Km), correlated with the dependent variable (households' intensity of perception towards agricultural extension service), negatively and significantly, as was presumed at 5% probability level. The effect of the credit center distance on farm households' intensity of perception showed that, when the credit center far from the household by one unit (1Km), the intensity of farm households' perception towards agricultural extension service showed to decrease by 7% probability level among the (total 812) sample households, by 0.0096 units among the total (812) sample households, by 0.0096 units among (807) uncensored sample households as indicated in Table 58. The finding of this study is in line with the finding of Ndambiri, *et. al.*, (2012) that distance of farmers from input output market (proxy for credit center distance) and farm households' perception on climate change (proxy for extension perception) showed negative and significant correlation.

The predictor, farm households' access to extension service the households' perception towards agricultural extension service correlated positively and significantly as was presumed, with 1% significant level. The effect of farm households' access to extension service, on their intensity of perception showed to increase by .0014% probability level among the total sample (812) sample households, by 0.214 units among the total (812) sample households, and by 0.214 units among the total (807) uncensored sample households as shown in Table 58. This study finding is in line with the study of Syngenta, (2014); Mamba (2016); Berhanu and Swinton (2001). Furthermore, farm households' participation in improved livestock production and the dependent variable (households' intensity of perception) towards agricultural extension service showed positive and significant correlation, as was presumed, with 1% significant level. The effect of the predictor on the dependent variable showed that when the farm households participated in improved livestock production, their intensity of perception, showed to increase by 0.001% probability level among the total (812) sample households, by 0.16 units among the total (812) sample households, and by 0.16 units among the total (807) uncensored households as indicated in Table 58. This finding is in line with the findings of Sarker and Itohara (2009); Neupane, *et. al.* (2002) that they have identified the importance of extension work and farm households' positive perception towards improved agricultural technologies adoption.

The predictor, farm household participation in off-farm activities and the dependent variable, sample households' intensity of perception towards agricultural extension service correlated positively and significantly as hypothesized at 10% significant level. The predictor, farm household's participation in off-farm activities influence to increase the dependent variable in that, as the predictor increase by one unit, the dependent variable showed to increase by 15% probability level among the total (812) respondents, by 0.097 units among the total (812) sample households, and by 0.097 units among the total (807) uncensored sample households as shown in Table 58. This finding is in line with the finding of Elias, *et. al.*, (2015), who concluded that farmers' satisfaction with extension service (a proxy variable for farmers' perception towards extension service) and off-farm income showed a positive and significant correlation. Furthermore, the predictor, farm households' participation in barley value addition practices and the dependent variable, farm households' intensity of perception towards extension service correlated negatively and significantly differently from presumption, and at 5% significant level

The predictor, farm households' participation in barley value addition influenced the dependent variable to decrease as indicted in Table 58, by 29% probability level, among the total (812) sample HHs, by 0.08 units among the total (812) sample HHs, by 0.08 units among the total (807) uncensored sample HHs, as indicated in Table 58, which revealed that farm HHs' participation in value addition practices, in this case in barley value additions, makes farm HHs to gain information and closer contact with extension workers that help them to have better perception towards extension service. Farm HHs, who close to cities participated in activities to enhance their income showed positive and significant correlation in the study of Kanwal, *et. al.*, (2016). However, in this study, participation in barley value addition practice to sale their barley crop and get better income affect the households' perception towards extension service negative effect which might be due to the fact that they may spent their time on their farm than moving to the cities to participate in income generating activities. As a result, they may not have adequate information about extension service and information about improved technologies.

CHAPTER EIGHT: KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

8.1. KEY FINDINGS

The current study was conducted in nine barley producing rural *kebeles*, selected from three *woredas* namely from *Ankober*, *Basona* and *Angollela woredas* of *Semen Shewa* Zone in *Amhara* Region, Central Ethiopia. The study was examined: (i) determinants of adoption of improved agricultural technologies that include farmland frequent plow (three or more time), chemical fertilizer, manure compost, frequent hand weeding (two or more times), weedicides, improved barley seed varieties and barley farm land drainage practice, which were adopted/used in barley production, (ii) their contribution in farm households' income and food availability, and (iii) farm households' perception and its determinants that farm households have towards the extension service to enhance their adoption, yield, income, and food availability statuses.

In this study, the findings on barley technologies adoption showed that, out of the total 812 sample households, 738 (90.89%) were adopters of one or more technologies, while the rest 74 (9.11%) were non-adopters. Furthermore, out of the total (738) adopters, farm land frequent plow were (74%), fertilizer (72%), manure compost (56%), frequent hand weeding (47%), weedicide (42%), barley farm drainage (27.50%), and improved barley seed varieties adopters were (19%). In addition, the predictors that affect the dependent variable, barley technologies adoption positively and significantly were farm land, food availability, income, credit access, extension access and participation in barley selling options, while market distance, household size, and household head age were affect barley technologies negatively and significantly.

In adoption of barley technologies in number, out of (812) respondents, one technology adopters were 5%, two technologies 12.4%, three technologies 16.30%, four technologies 22%, five technologies 14.7%, six technologies 11%, and seven and above number of barley technologies adopters were 9.6%. Farm households adoption showed variations in the number of barley technologies adoption, which might be due to their resource ownership, perception level, extension support, inputs costs and qualities. Moreover, the multivariate probit model analysis result showed that the likelihoods of barley farm land frequent plow adoption was 74%, fertilizer

72%, manure compost 6%, weedicide 42%, frequent hand weeding 47%, farm land drainage to avoid excess water out of barley farm land 28%, and improved barley seed varieties adoption was 20% probability level. In addition, the likelihoods of joint adoption and joint rejection of all barley technologies by all farm households showed 2% and 5% respectively.

In fertilizer adoption, as the censored Tobit regression model analysis result showed farm land size, food availability, income, credit access, extension service, participation in barley selling options, and in improved livestock production showed positive and significant effects; while those credit center distance and participation in *Belg* production (small rainy season production) showed negative and significant effects. In this study, it was observed that, adoption of improved barley technologies played the significant role in farm households' income and food availability improvement. The two sample t-test analysis result showed that, on average, the annual income of adopters' were higher by Eth. Birr 6853.14 than non-adopters. Regarding the food availability of adopters', their annual food availability on average showed higher by 1194295 Kcal than non-adopters. Although, there are many constraints that affect adoption such as high price, low quality of inputs, interest rate of credit, adoption of improved technologies are vital to improve farm households livelihoods by improving their yield, income and food availability.

The farm households' food availability and income statuses in the study area showed that, among total (812) sample households, (34.48%) were below the minimum (2550Kcal) food availability threshold; while the rest (65.52%) were with equal and above the minimum food availability threshold. Regarding their income status, out of (812) sample households, 51% were below the minimum income threshold, while the rest 49% were with income equal and above the minimum required income threshold (Eth. Birr 3781). In this study, almost 66% of farm households were with equal and above the minimum (2550Kcal) food availability threshold. On the other hand, loser to half of the sample farm households were with income equal and above the minimum (Eth. Birr. 3781) income threshold.

Regarding the sample households' food availability status by each technology adoption showed that, among (600) adopters of barley farm land frequent plow, 67% were with equal/above the minimum (2550Kcal) food availability threshold, among (583) fertilizer adopters 68%, among (453) manure compost adopters 71.52%, among (382) frequent hand weeding 69%, among (343) weedicide adopters 67%, among (223) barley farm land drainage adopters 72%, and among (160) improved barley seed adopters, 68% were with equal and above the minimum (2550Kcal) food availability threshold, which revealed that, out of the total adopters of each barley technology, the higher number (proportion) (67-72%) of adopters were with equal and above the minimum food availability threshold, while the rest (28-33%) of adopters were still with food availability status below the minimum required threshold.

The income status of adopter farm households by adoption of each barley technologies showed that, out of (600) total adopters of barley farm land frequent plow, 52 % were with income equal and above the minimum (Eth. Birr 3781) threshold, among (583) fertilizer adopters, 53%, among (453) manure compost adopters, 55%, among (382) adopters, 52%, among the total (343) weedicide adopters, 53%, among the total (223) barley farm land drainage adopters, 56%, and among 160 improved barley seed varieties adopters, (56%) were with equal and above the minimum income threshold, which revealed that the majority of barley technologies adopters (52-56%) were with income equal and above the minimum (Eth. Birr 3781) income threshold; while the rest (44-48%) of adopters were with income below the minimum threshold.

In the study area, barley is the major cereal crop produced and consumed widely by the highland farm households for their income and food source. In addition, its' straw is used for livestock feed and wall construction, and its stem for thatching of households' house roofs. Moreover, barley is used for the preparation of food and local beverages to be consumed by the community. Out of the total food availability, about 45% of food obtained from barley and the rest 55% from other different sources; and out of the total food availability, cereals cover 57.64%; and out of this cereal crops for food availability, the share of barley reached to 47%. On the other hand, the contribution of barley in farm households' income that, out of the total sample households' income, the share of crops was 53%, Livestock 32%, and other sources share was 15%. Out of the total income from different crops, the share of barley was 49%; the rest 51 % was from other crops. Furthermore, out of the total farm household's income, the share of barley was 26.11%, which revealed that barley in the study area is the most important crop for the farm households, although its production and productivity is limited by various constraints.

The male and female households' distribution by their income and food availability statuses that, out of (604) male sample HHs, (52%) were with income below the minimum threshold, while the rest 48% were with income equal and above the minimum threshold. However, the opposite is true in female sample households that, out of (208) female respondents, (52%) were with income equal and above the minimum threshold (Eth. Birr 3781), while the rest 48% were with income below the minimum threshold, which could be due to the fact that, female household heads are more responsible to save and take a care for their households' resources than male household head. Households' distribution based on their food availability status that, out of (604) male respondents, (34%) were below the minimum required food availability standard, while the rest (66%) were with equal and above the minimum (2550Kcal) food availability standard; and out of the total (208) female headed sample households, (37%) were below the minimum required food availability thresholds; while the rest (63%) were with equal and above the minimum threshold, which could be due to the fact that, male headed households are more productive than female households' in agricultural production including crops and barley.

The binary logit regression model analysis regarding factors affecting farm households' income status that livestock size, food availability, fertilizer adoption, credit access, participation in off-farm and in barley selling options, participation in improved livestock production affected the farm households' income status positively and significantly; while household size, market distance, and household head sex (being male) showed negative and significant effect. In food availability, access to extension service, compost adoption, frequent weeding, livestock ownership, farm land size, households' income played significant and positive impact; while household size, and frequent plow of barley farm land showed negative and significant effects.

The respondents' distribution by the study *woreda* and by their income status showed that, out of (414) sample households who were with income status below the minimum threshold (Eth. Birr. 3781), (50%) were from *Ankober*, (25%), from *Basona*, and (25%) were from *Angollela woreda*, which revealed that, the majority of farm households with income status below the minimum threshold were from *Ankober woreda* as compared to *Basona* and *Angollela woreda.* On the other hand, out of (398) sample households' with income status equal and above the minimum threshold, (16%) were from *Ankober*, (43%) were from *Basona*, and (42%) were from

Angollela woreda, which revealed that, the smallest size of respondents with income status equal and above the minimum were from *Ankober woreda,* while the higher proportion of sample households with income equal and above the minimum threshold were from the two *woredas,* (*Basona and Angollela*). The possible justification could be due to the sloppy and undulating land scape of *Ankober woreda* that resulted in high soil erosion that leads to low agricultural and barley production that also leads to low income farm household.

The respondents distribution based on their food availability status showed that, out of the total (280) sample households with food availability status below the minimum threshold (2550Kcal), (49%) were from *Ankober*, (31%) from *Basona*, and (20%) from *Angollela*, which revealed that, the majority of farm households with food availability status below the minimum threshold were from *Ankober woreda.* Regarding the (532) sample households, who were with food availability status equal and above the minimum (2500) threshold, (25%) were from *Ankober*, (35%) were from *Basona*, and (40%) were from *Angollela woreda*, which revealed that, the smallest size of respondents with food availability status equal and above the minimum standard were from *Ankober Woreda*. Hence, the majority of farm households from *Ankober woreda* were with lower food availability status as compared to *Basona and Angollela Woreda*.

The sample households' food availability status within the *woreda* showed that, out of the total (270) respondents in *Ankober*, (50%) were with food availability status below the minimum threshold, in *Basona*, out of (272) respondents, (32%) were below the minimum food availability status, in *Angollela,* out of (270) sample households, (21%) were below the minimum food availability status. Hence, farm households within the study *woredas,* showed that half of respondents in *Ankober,* and the majority (68% and 79%) in *Basona* and *Angollela woreda* were with food availability status equal and above the minimum (2550Kcal) required threshold, which revealed that farm households in *Basona* and *Angollela woredas* were better in food availability status than in *Ankober woreda*. It could be due to the fact that, in *Ankober woreda*, the land scape is undulating and sloppy that lead to soil erosion, which also leads to low soil fertility and low agricultural production that lead farm households to low food availability status.

Regarding the sample farm households' income distribution within the *woreda* showed that, out of (270) sample households from *Ankober woreda*, (76%) were with income below the minimum threshold, in *Basona woreda*, out of the total (272) sample households, (38%) were below the minimum income status, and in *Angollela woreda*, out of the total (270) sample households, (39%) were below the minimum (Eth. Birr 3781) income threshold. Therefore, the majority of sample households in *Basona* (62%) and *Angollela woreda* (61%) were with equal and above the minimum income threshold (Eth. Birr 3781) as compared to sample households in *Ankober woreda*. Therefore, sample households in *Basona* and *Angollela woredas* were much better in their income status than farm households in *Ankober woreda,* whose income was equal and above the minimum required income threshold were 24%.

In farm households' food availability from barley, farm land size, livestock ownership, income, fertilizer adoption, frequent hand weeding, participation in barley selling options, participation in *Belg* season production (small rainy season production), participation in land rent-in practice, and in rain fed crop supporting with irrigation affected positively and significantly; while weedicide adoption, household, frequent plow and improved barley seed varieties adoption showed negative and significant effects. Regarding the determinants of income from barley, food availability, fertilizer adoption, compost adoption, off-farm participation, participation in irrigation and *Belg* (small rainy season production) production, participation in barley value addition, and in land rent-in practice affected positively and significantly; while market distance, weedicide adoption, frequent weeding adoption, adoption of farm land drainage practice, and credit access affected negatively and significantly.

In this study, assessment of farm households' perception towards agricultural extension service as one of the study objective was conducted and in the analyses, Censored Tobit and ordered logit regression models were employed, in addition to descriptive statistics. As a result, the study results showed that, out of the total (812) sample households, (24%) were with low, (7%) with medium and (69%) were with high perception towards the importance of agricultural extension service in barley technologies adoption, thereby, to improve barley yield, and households' income and food availability. Hence, out of the total 563 respondents with high perception towards agricultural extension service, (93%) were adopters, which revealed that better perception towards extension help farm households to adopt improved barley technologies, thereby, to improve their production, income and food availability statuses.

The farm households' perception towards agricultural extension service and their food availability and income statuses showed positive association that, out of (563) respondents with high perception, (68%) were with food availability status equal and above the minimum threshold (2550Kcal), while the rest (32%) were with food availability status below the minimum threshold. Regarding their income status, out of (563) sample households with high perception towards extension service, (51%) were with income equal and above the minimum threshold (Eth. Birr 3781); while (49%) were with income below the minimum threshold. Therefore, out of the farm households' with high perception towards agricultural extension service, the majority of them were better their income and food availability statuses that were above and equal the minimum required threshold. Hence, better perception towards agricultural extension service help the farm households to adopt improved technologies that help them to enhance their yield, thereby, their food availability and income status.

The ordered logit regression model analysis result showed that farm land size, participation in improved livestock production, farmers' training center availability, adoption of number of barley technologies, frequent extension contact showed positive and significant effect on farm households' perception towards extension; while livestock size and credit center distance showed negative and significant effect. The censored Tobit regression analysis result also showed that farm land size, income, extension access, participation in improved livestock production and off-farm participation showed positive and significant effect; while credit center distance and participation in barley value addition practices showed negative and significant effects.

The focus group discussions showed that, in the study area, there were high inputs price that compete farm households' affordability; poor quality of inputs such as fertilizer and improved barley seed varieties, and high credit interest rate that all affect adoption, yield improvement, income and food availability of farm households negatively. As a result, farm households preferred to use compost instead of fertilizer, their own local seed than improved barley seed varieties, and refused to use credit service. However, farmers indirectly imposed to take credit, use fertilizer and improved seed to keep the companies/organizations' benefits than farmers'.

8.2. CONCLUSIONS

Based on the findings of the study, the following conclusions are drawn:

1. Among improved barley technologies, farm land frequent plow (three or more times), chemical fertilizer and manure compost were adopted by more than 50% of farm households; while frequent hand weeding (two or more times), weedicide, farm land drainage and improved barley seed were adopted by farm households below 50% of respondents.

2. Adoption of barely technologies has significant bearings on farm households' agricultural production, income and food supply, thereby, the farm households wellbeing.

3. In the study area, the qualities of improved agricultural inputs, such as fertilizer, and improved barley seed varieties were low, which led to low production and productivity of barley and other agricultural production and productivity. Furthermore, the prices of inputs were high, which compete the farmers' affordable capacity.

4. Formal credit service in the study area has given to the farming community in different forms, such as in kind and in cash. However, its interest rate is to high to the farmers' affordable capacity. In addition, the time of repayment of credit is during the harvest time, which is the time when the price of agricultural production are low. Hence, most of the benefits produced using improved technologies are used for credit repayment.

5. Among the study *woredas*, in *Ankober woreda*, adopters' number were less as compared to *Basona* and *Angollela woreda*, due to its land scape, which is sloppy and undulating that exposed for erosion. Hence, farm households do not use improved technologies such as fertilizer. Then, farmers are not volunteer to use fertilizer since it is eroded. It is not only fertilize, farmers are not volunteer to use even other improved technologies except soil and water conservation practice.

6. The majority of sample households' income and food availability statuses in Ankober woreda were low as compared to the two woredas, *Basona and Angollela*. It is due to many factors such as low improved inputs usage, due to sloppy areas of farm land that exposed for soil

erosion that reduces soil fertility that resulted to low production, low income and low food availability. In addition, it is due to poor quality of improved inputs.

7. The majority of farm households' perception towards agricultural extension service in the study area was high, which showed that farmers are interested to get extension service, but the high cost of inputs, high interest rate of credit service, inconvenience of credit repayment time limit them to adopt inputs such as fertilizer and improved seed varieties widely.

8. Farmers in the study area prefer manure compost adoption as compared to fertilizer it is because of high cost of fertilizer, poor quality, credit repayment time inconvenience. As a result, adoption or use of fertilizer is more preferred by farmers. Furthermore, compost is preferred, because, it increases the soil mass, no cash cost for it, a one time application of compost can serve up to three years to improve barley or other agricultural yields. However, its application/use is constrained by heard size and its use for fuel.

9. Farmers in the study area prefer to use their local barley seed varieties than to use improved barley varieties, due to the low resistance characteristics of improved barley seed varieties as compared to the local varieties. Local varieties are better frost, weed and diseases resistance as were confirmed by the focus group discussion participants conducted in this study.

10. Farm households in the study area are involved in small rainy season (*Belg), main* rainy season (*Mehere/Kiremt*) and using irrigation. Farmers use improved technologies like fertilizer during main rainy season as compared to small rainy season.

8.3. RECOMMENDATIONS

In the study area, it needs to enhance farm households' barley technologies adoption, thereby, yield income and food availability by alleviating adoption constraints such high price and poor quality of inputs; by improving market and infrastructure services, and through farmers' training, and proper extension services

Credit service in the study area was constrained by high interest rate. Hence, it was difficult for the farm households to use credit and invest on improved barley technologies. Therefore, the interest rate of credit should be reduce to the level that can be affordable by the farm households;

In the study area, there are farm households with low food availability and income statuses. Hence, it is necessary to give high attention to improve their income and food supply through adoption promotion of improved agricultural and barley technologies, through improving inputs quality, reducing high prices of inputs and credit interest rate and arranging credit repayment time in the convenience of farmers.

To improve more the farm households adoption, income, food availability and perception level towards extension service in *Ankober woreda,* measures such as promotion of soil and water conservation practices that help to protect soil erosion, improving of inputs quality, designing of income generating schemes to improve their income and inputs buying capacity that help them to improve their adoption capacity, yield, income and food availability.

The majority of farm households were with high perception towards the importance agricultural extension service. However, only high perception towards agricultural extension service is not enough for better adoption, income and food availability. Therefore, it is necessary to create conducive environment for better adoption, thereby, better income and food availability through improving inputs quality and reducing their costs and reducing the high credit interest rate.

Farmers in the study area are inclined towards adoption/use of compost than to adopt fertilizer on their barley production to improve its yield, then, the income and food availability of the household. But, compost adoption is constrained by heard size and its use for fuel. Therefore, it is important to promote other means to substitute its use for fuel through promotion of stove and fuel wood production through backyard forest development at household level.

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ANNEXES

Annex 1. Independent Variables Description

Annex 1.1. Independent variables description used in barley technologies adoption (13 explanatory variables with 5 continuous and 8 non-continuous)

Household head age in (years): it is a continuous variable hypothesize to affect farm households' barley technologies adoption negatively and significantly. The older farmers are less likely to adopt and allocate farm land to improved technologies (Hailu, 2008). According to Daniel (2008);Bekele (2008), age is a factor that makes farmers to confine more to household duties and traditional practices. It was assumed to have a negative relationship with information utilization, thereby, improved agricultural technologies. However, young farmers are expected to have the chance to be educated and exposed to new technology and less inclined to promote indigenous practices and crops like barley (Fetien, *et. al*, 2009).

Household's Livestock size (TLU): it is a continuous variable to be measured in Total Livestock Unit (TLU) that expected to associate positively and significantly with barley technologies adoption. As the size of livestock increases, households' adoption of barley technologies is expected to increase. It is because, livestock ownership and its higher size in (TLU) or in number serves as proxy for wealth status (Chilot et al., 1996; Asfew, *et. al.*, 1997). Livestock is generally considered to be an asset that could be used either in the production process or be exchanged for cash or other productive assets. Hence, the livestock holdings of the household affects farmers' adoption of improved technologies positively and significantly. Studies by Kidane (2001); Birhanu (2002); Techane (2002); Endrias (2003); Degnet, *et al.* (2001); Chilot (1994) found that livestock holding has positive and significant influence on adoption of improved agricultural technologies.

Household's farm land size (Ha): it is the continuous variable, hypothesized to associate with households' barley technologies adoption positively and significantly. As household's farm land size increases, households' barley technologies adoption is expected to increase. According to, Reij and Waters-Bayer (2001), owners of big farms are often rich, have access to more resources, including information, and can better afford failed experiments. Furthermore, with regard to the relationship of land holding with adoption, a study conducted by Itana (1985); Wolday (1999); Mulugeta (2000); Million and Belay (2004); Yishak (2005) indicated positive relationship between farm size and adoption. However, according to Chi and Yamada (2002), Abrhaley (2006), Endrias (2003), Abiro, *et. al.*, (2017) large farm size made low adoption that it correlated negatively with technology adoption.

Household's home distance from market (Km): it is a continuous variable expected to associate positively and negatively with farm households' barley technologies adoption. This hypothesis is supported by the studies conducted by Alemitu (2012); Minyahil (2008); Bayissa (2010); Romina, *et. al.* (2010). However, the study by Abiro, *et. al.*, (2017), distance of markets from residence of farm households affects probability of adoption of malt barley positively at 1% level of significant. This is because of the reason that in the study areas farmers near to the main market center allocated their farm land for alternative commodities. Market actors on malt barley are collecting the grain from the growers in far places from market center. Farmers far from market center were able to sell their produces.

Household head formal education in (yrs) of schooling: formal education is measured in terms of years of formal schooling the respondent has completed. Some studies indicate that innovators are better educated (Reij and Waters-Bayer, 2001). It is a continuous variable expected to associate positively and significantly with household's barley technologies adoption. According to Assefa and Gezahegn, (2009), it is because education improves the access to information and new ideas and inputs provided by extension workers. Education may make a farmer more receptive to advice from an extension agency, or highly able to deal with technical recommendations that require a certain level of numeracy or literacy.

Household head sex: it is nominal variable to be used as a dummy (1 if male, 0 otherwise) hypothesized to affect household's adoption of barley technologies negatively and significantly. In most adoption theories male headed households are better adopters of improved technologies than female headed ones. According to Reij and Waters-Bayer (2001), although women share a large farm work, it is usually the men who are the household heads and represent the family in public, and are most likely to take credit for any changes made on their farms. Sex difference is one of the factors expected to influence adoption of technologies. According to Techane (2002), due to many socio-cultural values and norms, males have freedom of mobility and participation in meetings and consequently have better access to information that help them adoption.

Household's income status: it is a non-continuous variable indicating whether the household is below or equal and above the minimum standard, which then has been expected to associate positively and significantly with household's barley technologies adoption. Hence, households equal and above status are expected to adopt barley technologies and vice-versa. Kidane (2001); Degnet, *et. al.* (2001) have reported the positive influence of household's income on adoption of improved technologies. The farm HHs' income is the total annual earnings from crops, livestock and livestock products, etc., selling. This is believed to be the main source of capital for purchasing inputs. Thus, farm HHs with a relatively higher level of income are likely to purchase improved and essential agricultural inputs in order to use on their agricultural production.

Household's credit access: it is a dichotomous explanatory variable hypothesized to influence adoption of barley technologies positively and significantly. If the household has access to credit, he/she is expected to adopt agricultural technologies. if a farm household, used credit, represented by one (1), but, non-user Zero (0). Improving credit access regarded as the key element to increase agricultural productivity and alleviate poverty (Adugna and Heidhues, 2000) since credit enables to relax the liquidity constraints of smallholder farmers to improve their risk bearing capability, and influencing adoption of new technology (Feder, *et. al.*, 1985; Tesfaye, 2003). studies on adoption of cereals by Mwannga, *et. al*. (1998); Kansana, *et.al.* (1996); Legesse (1992); Mulugeta (1994); Chilot, *et. al.* (1996); Asfaw, *et. al.* (1997); Tesfaye, *et. al*. (2001); Wolday (1999); Bekele, *et. al.* (1998).

Household's access to agricultural extension service: it is a non-continuous variable hypothesized to correlate positively and significantly with barley technologies adoption. As farm household's access to agricultural extension service increases, their adoption of barley technologies is expected to increase. According to Kidane (2001); Kansana, *et. al.* (1996);

Nkonya, *et. al.* (1997); Aregay (1980); Chilot, *et.al*.(1996); Tesfaye, *et. al.* (2001; Birhanu (2002); Techane (2002); Haji (2003);Endrias (2003), there is a significant and positive relationship between access to extension and adoption of agricultural technologies.

Household size in Adult Equivalent: it is a continuous variable expected to correlate negatively and significantly with barley technologies adoption; because, HHs' consumption may increase and may create financial constraint on HHs' to buy and use improved technologies. According to Bekele and Holden (1998), Hilina (2005), Abebaw (2003); Tesfaye (2005); Yilma (2005), Wagayehu and Darke (2003), family size increases the probability of HHs to be food insecure.

Household's food availability status: it is the non-continuous (dichotomous) explanatory variable that indicates whether the HH is below or equal/above the minimum food availability standard. When the farm HH is equal/above the minimum threshold/standard, it is assumed that the household is in a better economic status/position. Hence, the household can invest on improved agricultural technologies. Therefore, the household with better food availability status, in this study, when the farm household's food availability status is equal/above 2550 Kcal, the household is expected to adopt barley technologies. Hence, household's better food availability status is expected to correlate positively and significantly with barley technologies adoption. The study conducted by Kidane (2001); Degnet, *et. al.* (2001) and Getahun (2004) showed that households with better economic position/status can adopt improved technologies.

Household's participation in barley output market options: it is a non-continuous variable hypothesized to associate positively and significantly with household's barley technologies adoption. In this study, farm households' participation in barley selling using different selling options can help farm households to sell their barley output that can enhance their financial capacity, which in turn help to purchase and use improved agricultural technologies to use in their barley production. The different barley selling options farm households use to sell their barley output include cooperatives, whole seller, open market, individual consumer to sell their barley with better price. According to Tigist (2017), markets open the opportunity to farm households to sell farm outputs that help them to buy improved inputs and tapa range of public and private services such as extension and credit access service, which help them to remain economically self-sufficient and maintain food security.

Household's participation in land rent-in practice: land and livestock were used as proxies for wealth endowment. Wealth enhances risk taking and the probability that a farmer will invest in new technology. Farmers with a bigger land holding will be more likely to set aside extra land to practice new technology (Jera and Ajayi, 2008). It is a non-continuous variable expected to affect positively and significantly farm households' barley technologies adoption.

Annex 1.2. Description of Independent Variables hypothesized to affect Fertilizer adoption (13 explanatory variables with 6 continuous and 7 non-continuous)

Household head age (years): it is a continuous variable hypothesize to affect farm households' fertilizer adoption negatively and significantly. It is because old people may not have the labor power required to practice and apply fertilizer and may not participate in off-farm income to get income and buy fertilizer; and it may be due to the reluctant behavior of the old people to innovation and new practices. According to Hailu (2008), the older the farmer the lower is the probability to adopt and allocate area to improved technologies. According to Daniel (2008) and Bekele (2008), old age is a factor that makes farmers to confine more to household duties and traditional practices. Hence, age would have a negative relationship with information utilization, thereby, improved agricultural technologies. However, young farmers are expected to have a chance to be educated and exposed to new technology and less inclined to promote indigenous practices like in barley (Fetien, *et. al*, 2009).

Livestock Size (TLU):it is a continuous variable measured in Total Livestock Unit (TLU) expected to associate positively with farm households' fertilizer adoption. In this study, it was presumed that livestock ownership and farm households' fertilizer adoption was presumed to associate positively and negatively. It is supported by the study of Chilot, *et. al.,* (1996 and (1994); Asfew, *et. al.,* (1997); Habtemariam (2004); Wegayehu (2003); Birhanu (2002); Techane (2002); Endrias (2003); Degnet, *et.al.,* (2001) have found that livestock holding has positive influence on adoption of improved technologies.

HHs' oxen ownership in number: measured by the number of oxen the household has. It Plays important role in farm land cultivation. The households who use oxen can better cultivate their farm land on time that help farmers to get better yield, thereby, can purchase fertilizer and use in their production of barley that in turn increase the barley yield, which enhance the farm households' food availability and income status improvement as well as poverty reduction. In this study oxen ownership and fertilizer adoption is hypothesized to correlate positively and significantly. The number of oxen owned by the household is an important source of draught power and important source of income when they retire after few years of traction. Jayne, *et. al*., (2003) found a positive association between landholding and asset, specifically ownership of oxen. It is therefore, logical to expect that ownership of higher number of oxen increase the fertilizer adoption of farm households (Mintewab and Holden, 2006).

Farm land size (Ha): it is the continuous predictor, hypothesized in this study to associate with households' fertilizer adoption positively and significantly. When the farm household's land size increases, households' fertilizer adoption expected to increase. The relationship of land holding with adoption, studies conducted by Itana (1985); Wolday (1999); Mulugeta (2000); Reij and Waters-Bayer (2001), Million and Belay (2004) and Yishak (2005) concluded the positive and significant relationship between farm size and adoption. However, large farm size made low adoption that it correlated negatively with technology adoption (Chi and Yamada, 2002; Abrhaley, 2006; Abiro, *et. al.,* (2017).

Market distance (Km): it is a continuous variable expected to associate positively and negatively with farm households' fertilizer adoption. Farmers far from market center were able to sell their produces. it is a continuous variable expected to associate positively and negatively with farm households' barley technologies adoption. These hypothesis is supported by the studies conducted by Alemitu (2012); Minyahil (2008); Bayissa (2010) and Romina, *et. al.* (2010). However, the study by Abiro, *et. al.,* (2017), market distance affects the probability of farm households positively and significantly. This is because, farmers near to the main market center allocated their farm land for alternative commodities.

HHs' home distance from FTC in Km: the continuous variable hypothesized to correlate negatively and significantly with farm households' fertilizer adoption. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market expected to affect farm households' adoption of fertilizer negatively and significantly.

HHs' home distance from DA office in Km: it is a continuous explanatory variable measured in (Km) expected to influence farm households' chemical fertilizer adoption negatively and significantly. In the study of Ndambiri, et. al., (2012), the distance of farmers from input output market showed negative and significant correlation with improved technologies adoption. As the distance of DAs center increases from where the farmers' household live and work the frequencies of farmers contact with DAs decreases. Thus, development agents' center would negatively influence household heads participation in extension services.

Credit center distance Km: it is a continuous variable presumed to affect farm HHs' chemical fertilizer adoption negatively and significantly. As farm households' far from the credit center, their chemical fertilizer adoption decreased due to the fact that they may not easily access to information and the availability of fertilizer. Hence, they may not use chemical fertilizer. Hence, credit center distance and farm households' chemical fertilizer adoption has expected to associate negatively and significantly. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market affect negatively their adoption of improved agricultural technologies.

All weather distance Km: it is a continuous predictor measured in Km that farm households' home distance from all weather road, then to transport facilities (vehicles). This is expected to have a positive relationship with adoption of fertilizer in barley production.

Households formal education (years): formal education is measured in years of formal schooling that the respondent completed. It is a continuous variable expected to associate positively and significantly with HH's fertilizer adoption. Studies indicate that innovators are better educated (Reij and Waters-Bayer, 2001); and education improves information and new ideas and input access. It makes farmers more receptive of extension advice, or help to deal with technical recommendations that require numeracy and literacy (Assefa and Gezahegn, 2009).

Household size (Adult equivalent): it is a continuous variable expected to correlate negatively and significantly with fertilizer adoption; it is because, HH's consumption may increase that create financial constraint on household to buy and use improved technologies. Households with large family size may perceive higher risk of starvation than those with smaller family size and seem to accept less risk in experimenting with new technologies. Households with bigger family size are more likely to be poor and food insecure than household with relatively small family size (Hilina, 2005; Abebaw, 2003; Tesfaye, 2005; Yilma, 2005; Wagayehu and Darke, 2003).

Household's dependency ratio: it is a continuous explanatory variable hypothesized in this study with the expectation that it may affect fertilizer adoption negatively and significantly. This indicates that with increase in dependency ratio the ability to adopt chemical fertilizer is expected to decline. When the dependency ratio increase, the ability of farmers to meet family needs decrease (Jansen, *et .el.,* 2004).

Household sex: it is the nominal variable used as dummy variable (1 if male, 0 otherwise), hypothesized to affect household's barley technologies adoption negatively and significantly. In most adoption theories, male headed households are better adopters of improved technologies than females. According to Reij and Waters-Bayer (2001), although women do a large share of the farm work, it is usually the men who are household heads and represent the family in public. Sex difference is one of the factors affecting adoption of new technologies. According to Techane (2002), due to many socio-cultural values and norms, males have freedom of mobility and participate in meetings and consequently have better access to information that help them to adopt improved technologies.

Household food avail. Status: in this study, it is a dichotomous variable indicating that, when the farm household is below or equal and above the minimum threshold/standard, which then has been expected to associate positively and significantly with household's fertilizer adoption, in this study. Hence, households with equal and above 2550 Kcal, or below 2550 Kcal statuses are expected to adopt fertilizer adoption positively and significantly. According to Kidane (2001); Degnet, *et. al.,* (2001); Getahun (2004), households' better economic position can associate with adoption of improved agricultural technologies positively and significantly.

Household income status: it is a non-continuous/dichotomous variable indicating whether the household is below; or equal and above the minimum standard, which then has presumed to associate positively and significantly with household's fertilizer adoption. Hence, households equal and above status are expected to adopt barley technologies and vice-versa. According to Kidane (2001); Degnet, *et. al.* (2001); Getahun (2004) have reported the positive influence of household's income on adoption of improved technologies.

Farm households credit access: in this study, credit access is the non-continuous variable hypothesized to influence fertilizer adoption positively and significantly. Improving credit access often regarded as the key strategy for increasing agricultural productivity and to alleviate poverty (Adugna and Heidhues, 2000). It enables to relax the liquidity constraints that smallholder farmers' face to improve their risk bearing capability, influencing adoption of new technology. Utilization of credit may enable farmers to purchase inputs or acquire physical capital, thus contributing to technology adoption (Feder, *et. al.*, 1985; Tesfaye, 2003).

Farm households access to Agricultural Extension service: it is a non-continuous variable that hypothesized in this study to correlate positively and significantly with fertilizer adoption. As farm household's access to agricultural extension service increases, their fertilizer adoption showed to increase. According to Kidane (2001); Degnet (1999), Kansana, *et. al.*, (1996); Nkonya, *et. al.* (1997); Aregay (1980); Chilot, *et. al.*(1996); Tesfaye, *et. al.* (2001); Birhanu (2002); Techane (2002); Haji (2003) and Endrias (2003) there is a significant and positive relationship between access to extension and adoption of agricultural technologies.

Farm households' participation in barley selling options: in this study, farm households' participation in barley selling options help them to sell their barley output and enhance their financial capacity, which in turn help them to purchase and use improved technologies such as fertilizer. In this study, farm households use different barley selling options such as cooperatives, whole seller, open market, individual consumers to sell their barley. Therefore, farm households' participation in different barley selling options to sell their barley was hypothesized to correlate with fertilizer adoption positively and significantly. As farm households use different options to sell their barley, their fertilizer adoption probability was expected to increase, which is supported by the study result of Tigist (2017).

Household part land-rent-in land and livestock were used as proxies for wealth endowment. Wealth enhances risk taking and the probability that a farmer will invest in new technology. Farmers with a bigger land holding will be more likely to set aside extra land to practice new technology (Jera and Ajayi, 2008). It is a non-continuous variable expected to affect positively and significantly farm households' fertilizer adoption.

HHs' marital status: it is a variable used to show the households' marital status in the study area. The variable is represented as a categorical variable that takes a value (1) for unmarried, (2) married, (3) Divorced, and (4) Widow/Widower. By tradition, in rural areas, parents arrange marriage of their sons and daughters and there are dowries of home goods, livestock and even land given to the brides from both parents. Therefore, it is hypothesized that being married through arranged marriage would be positively related to participation in leasing-in and leasing-out land. Furthermore, the married ones may have better motivation to enhance their resources. Hence, marital status played a significance and positive role in fertilizer adoption of the households. In this regard, marital status and fertilizer adoption of farm households are expected to associate positively and significantly. Marriage is established with a view of helping each other. Married people not only pool their resources but also reduce cost that would have been spent separately. Moreover, married households put aside some resources for unforeseen circumstances to smoothen their life (Hilna, 2005; Aschalew, 2006). In particular, for a lady to stay in marriage in rural community would have a significant influence on supply of labor, access to land and other socio-economic privileges in the society (Assefa, *et.al*, 2004). Therefore, it is hypothesized that HHs who are in marriage are more likely to be non-poor than those without marriage (i.e. not married, divorced/separated or widowed).

HHs' participation in livestock shared-in: it is the dummy explanatory variable that shows whether the farm households' involve in Livestock shared –in or not. It takes the value 1 when the farm household is participated in livestock shared-in practice, which expected to increase livestock holding and benefits from livestock, thereby, to increase farm household's income.

When the farm households' income increase, their adoption of fertilizer through purchasing or using credit by paying pre-payments. Hence, farm households' participation in livestock shared-in practice and fertilizer adoption are expected to associate positively and significantly. Studies by Getachew (1995),Woldehanna; Alemu (2002), Hilna (2005); Chilot (2006) showed that HHs with more livestock holding can have good access to animal diet (meat, milk and milk bi-products) more draft power and manure for crop production.

Farm household's income participation in irrigation production: it is the non-continuous explanatory variable, expected to affect farm HHs' intensity of chemical fertilizer adoption. Participation in irrigation production has expected to get additional barley crop yield that can enhance HH's income, thereby, to purchase fertilizer and adopt/use it. Hence, farm HHs' participation in irrigation production and chemical fertilizer adoption were hypothesized to correlate positively and significantly. Irrigation production played significant role in enhancing the farm HHs' income through yield improvement Sikwela (2008); Fanadzo (2012).

Farm households' participation in *Belg* production: it is the non-continuous explanatory variable, expected to affect farm households' intensity of chemical fertilizer adoption positively and significantly. Participation in *Belg* (small rainy season) production helps farm households to get additional yield that can improve income, which help farm households' to purchase and adopt chemical fertilizer. Therefore, in this study, farm households' participation in *Belg* barley production and their intensity of chemical fertilizer were hypothesized to correlate positively and significantly, which was supported by the study of Sikwela (2008) and Fanadzo (2012) conducted on the role of participation in irrigation production (a proxy for *Belg* production participation) in addition to the main season production which help to improve farm households' income, thereby, purchasing and adoption of fertilizer.

HHs' participation in rain fed crops support with irrigation: it is a non-continuous and dichotomous explanatory variable expected to affect the intensity of chemical fertilizer adoption positively and significantly. Supporting rain fed crop with irrigation can increase agricultural crops yield that can be use for sale and purchase agricultural inputs such as fertilizer. Hence, farm households' participation in supporting of rain fed crops and their intensity of chemical fertilizer adoption can help farm households crop yield to increase and the surplus yield can be sold and used to purchase improve agricultural inputs such as chemical fertilizer (Bogale and Shimelis (2009). Therefore, in this study, farm households' participation in support of rain-fed crop with irrigation and the intensity of chemical fertilizer adoption are hypothesized to correlate positively and significantly.

HHs' participation in improved livestock production: it is a non-continuous predictor, expected to affect farm HHs' intensity of chemical fertilizer. Participation in improved livestock production takes the value (1) for participants, and (0) for non-participants. Farm households who have participated in improved livestock production are expected to take information on their improved livestock and are expected to have better information on chemical fertilizer. As a result, in this study, farm household's chemical fertilizer adoption and participation in improved livestock production are expected to associate positively and significantly. Members of farm households which are relatively well-off are likely to purchase and use improved technologies including fertilizer help them to adopt fertilizer (Kanwal, *et. al.,* 2016).

Annex 1.3. Description of Independent Variables hypothesized to affect farm households' perception level towards extension (14 predictors 7 continuous and 7 non-continuous)

Household's head age in years: it is the continuous variable measured in years that hypothesize to associate negatively with households' perception towards agricultural extension service. In this study, it is assumed that as farm household head's age increase, the household's perception towards agricultural extension service is expected to decreased, because, old age people are assumed to be reluctant to new technologies and practices. However, the farmers' climate change perception and farm households' age showed positive correlation as indicated in the study of Ndambiri, *et. al.,* (2012).

Household's head formal education in years of formal schooling: it is a continuous variable measured in years of formal schooling. It is hypothesized that household head formal education and household's perception towards agricultural extension service have positive and significant association. It is because education is assumed helpful to seek, analyze and interpret information. Hence, educated farm households are assumed better in analyzing the importance of extension service and develop positive attitude and better perception towards agricultural extension service. In the study of Ndambiri, *et. al.,* (2012), education level of the farmers and their perception on climate change showed positive and significant correlation.

Household size in adult equivalent: it is a continuous variable measured in adult equivalent hypothesized to associate negatively and significantly with farm households' perception to extension service. As farm households' size increases, households' participation in use of improved technologies is expected to decrease; since households' give more time and information seeking to fulfill their household members' consumption than giving time to attend and make contacts. Hence, farm HHs' size and their perception to extension service is expected to correlate negatively. According to Uddin, *et. al.,* (2017), family size and farm households' perception on climate change showed negative correlation.

Household's Livestock size (TLU): it is a continuous variable measured in TLU hypothesized in this study to have a positive association with farm households' perception towards extension service. When the farm households' livestock ownership increases, their inclination to extension service for their heard is expected to increase. Hence, households with high livestock size and their perception towards agricultural extension service is has expected to correlate positively and significantly. It is supported by the study of Aklilu, *et. al.,* (2016) that households' livestock ownership correlates positively and significantly with households' perception towards climate change variability such as rain fall.

Household's farm land size (Ha): it is a continuous variable measured in hectare, hypothesized to correlate with farm HHs' perceptions to extension service. positively and significantly. Farm HHs with large farm size shows the better position of the farm HHs' resource ownership that gives them better opportunity to invest on improved technologies. Hence, farm size and perception of farm HHs' towards extension service is expected to associate positively and significantly. In the study of Uddin, *et. al.,* (2017) farm size and farmers' perception towards climate change showed negative and significant relationship; and in the study of Aklilu, *et. al.,* (2016), farmland owned by HHs is related to perceptions positively and significantly.

Credit center distance (Km): it is a continuous variable presumed to affect farm HHs' perception negatively and significantly. As farm HH' far from the credit center, they may hesitate to go far distance and take credit and invest it on improved agricultural technologies. Hence, credit center distance and farm HHs' perception towards agricultural extension service has expected to associate negatively and significantly. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market/ proxy for the predictor input output market and farm households' perception on climate change showed negative and significant correlation.

Market distance (Km): it is a continuous explanatory variables measured in (Km) expected to affect farm HH's perception level towards extension service offered in the study area. It is expected that when the farm households are far from the market center, the also far from information, DAs contact and from access to improved technologies. Hence, farm households far from market center are expected to have low perception towards agricultural extension service. As a result, in this study, market distance and farm household's perception level has presumed to be associated negatively and significantly. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market/ proxy for the predictor input output market and farm households' perception on climate change showed negative and significant correlation.

Household's head sex: it is a non-continuous variable that takes the value of (1), when the farm household head is male; otherwise (0). In general, males are more familiar and exposed to external environment and have wider communication outside their family members and have various social linkages than females. As a result, the male farm HH heads' sex and perception level are expected to correlate positively and significantly. In the study of Kisauzi, *et. al.,* (2012) female farm households access to extension service showed significant limitation than male farm households. Hence female access to extension and their perception towards climate change showed negative correlation. In addition, in the study of Komba, *et.al.,*(2018), on decentralization extension effectiveness, which correlated negatively with females' perception.

Households' food availability status: it is a non-continuous variable expected to have a positive and significant association with farm households' perception towards agricultural extension service. The farm households with food availability status is equal/above, the threshold

2550Kcal, the household is considered as better in food availability status; while below the threshold, the household is in low food availability status. As a result, farm households' food availability status and their perception towards agricultural extension service is expected to associate positively and significantly. The study conducted by Kidane (2001); Degnet, *et. al.* (2001); Getahun (2004) showed that households with better economic position/status can develop interest and adopt improved technologies.

Households' participation in improved Livestock Production, it is a dichotomous variable that has expected to correlate with the farm households' perception towards agricultural extension service positively and significantly. In this study, farm households, who have participated in improved livestock production are presumed to have better perception towards agricultural extension service. When the farm households are participated in improved livestock production, it takes the value (1), one; otherwise (0) Zero. It is supported by the study of Aklilu, *et. al.*, (2016) that households' livestock ownership (proxy variable for households' participation in livestock production) correlate positively and significantly with households' perception towards climate change variability such as rain fall.

Households' income status: it is a non-continuous variable that has been hypothesized to associate positively and significantly with farm HH' perception towards extension service. When the income status of the farm households is better, the farm households' information seeking and their contacts with other for better and further income status is expected to increase. Hence, farm households' income status and their perception towards extension service was presumed to correlate positively. When the farm households' income status is equal/above the threshold (Et. Birr 3781) income, it takes the value (1) one; otherwise, Zero (0). It is supported by the study result of Deressa, *et. al.*, (2011) that farm households' income and climate change perception (proxy predictor for extension perception) showed positive and significant relationship.

Farmers' training center availability, the non-continuous variable hypothesized to correlate positively and significantly with farm HHs' perception towards extension service. The availability of farmers' training center gives farmers opportunity to access information how to improve their production. Hence, their perception towards extension is expected to improve to higher level in that when the farmers' training center is available in the rural kebele, the farm households' perception towards extension service, expected to increase from lower level to higher level. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market/a proxy predictor for farmers training center availability in the farmers' proximity and farm households' perception on climate change showed negative and significant correlation.

Number of barley technologies adoption: it is the categorical explanatory variable that described the number of barley technologies adopted by farm households. The categories include (0) for non-adopters, (1) for 1-2 technologies adopters, (2) for 3-4 technologies adopters, (3) 5-6 technologies adopters; and (4) seven (7) and above number technologies. It is hypothesized that as the number of barley technologies adopted by the farm households' increased, their perception level towards agricultural extension also increased. Hence, number of barley technologies and farm households' perception level towards extension service are hypothesized to correlate positively and significantly. Members of farm households which are relatively well-off are likely to purchase and use improved technologies than poor farm households (Kanwal, *et. al.*, 2016).

Frequency of extension contacts between farm households and the extension worker: it is a categorical variable that shows on average the monthly contacts of farm HHs and extension worker to exchange extension information. The contacts of farm households with extension worker within a month are represented by (1) for one contact, (2) for two contacts, and (3) for three and more contacts, and (0) for no contacts. In this study, extension contact is considered as important factor to enhance the farm households' perception level towards agricultural extension service offered in the area positively and significantly, which is supported by the study the study conducted by Elias, et. al., (2015). Furthermore, extension service provided to farmers is the major source of new information in the study area. It is therefore hypothesized that time of contact with extension agents will increase farmers knowledge (Bekele and Holden, 1998). The frequency of contact between a farmer and development agent has the potential force to accelerate effective dissemination of adequate agricultural information that in turn enhances farmers' decision to adopt agricultural technologies (Kidane, 2001; Degnet, 1999).

Annex 1.4. Description of predictors affecting farm households' intensity of perception towards extension service (13 predictors with 8 continuous and 5 non-continuous variables)

Household age (years):it is the continuous explanatory variable measured in years that hypothesized to associate with farm HHs' mean perception (intensity of perception) towards extension service negatively and significantly. It is assumed that as the farmers' age increase, their perception towards new ideas and innovation become reluctant. Hence, in this study, the household's perception towards agricultural extension service and their age expected to associate negatively and significantly. However, the farmers' climate change perception and farm household's age showed positive correlation as indicated in the study of Ndambiri, *et. al.,* (2012).

Household's head formal education (years of schooling): it is a continuous variable measured in years of formal schooling education. Farm household head formal education help farm households to search information, create linkage with knowledge based information sources such as (DAs) and analyze the information they access. Therefore, farm households who have formal education are expected to have better perception towards agricultural extension service. As a result, in this study, farm households with formal education and their perception towards agricultural extension are expected to associate positively and significantly. In the study of Ndambiri, *et. al.,* (2012), education level of the farmers and their perception on climate change showed positive and significant correlation.

Household's Livestock size (TLU): it is a continuous variable measured in TLU. It is hypothesized in this study to have a positive association with farm households' perception towards agricultural extension service. When the farm households' livestock ownership size increases, their inclination to get better extension service to manage better their heard is expected to increase. Hence, households with high livestock size and their perception towards agricultural extension service has hypothesized to correlate positively and significantly. It is supported by the study of Aklilu, *et. al.,* (2016) that households' livestock ownership correlates positively and significantly with households' perception towards climate change variability such as rain fall.

Household's farm land size (Ha): it is a continuous variable measured in hectare (Ha) that hypothesized to correlate with farm households' perceptions towards extension service positively and significantly. Farm households with large farm size shows the better position of the farm households' resource ownership that gives them better opportunity to invest on improved technologies. Then, they are expected to seek information how to use improved agricultural technologies. Hence, farm size and perception of farm households towards agricultural extension service is expected to associate positively and significantly. It is supported by the study of Aklilu, *et. al., 2016*. The size of farmland owned by households is related to perceptions on number of extreme cool days and warm nights showed positive and significant correlation.

Credit center distance (Km): it is a continuous variable presumed to affect farm HHs' perception negatively and significantly. As farm HHs' far from credit center, they may hesitate to go far distance and to take credit and to invest on improved agricultural technologies. Hence, credit center distance and farm households' perception towards agricultural extension service has expected to associate negatively and significantly. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market/ proxy for the predictor input output market and farm households' perception on climate change showed negative and significant correlation.

Market distance (Km): it is a continuous explanatory variables measured in (Km) expected to affect farm household's perception intensity that they have to agricultural extension service offered in the study area. It is expected that when the farm households are far from the market center, the also far from information, DAs contact and from access to improved technologies. Hence, farm households far from market center are expected to have low perception towards agricultural extension service. As a result, in this study, market distance and farm household's perception intensity has presumed to be associated negatively and significantly. In the study of Ndambiri, *et. al.,* (2012), the distance of farmers from input output market and their perception on climate change showed negative and significant correlation.

Household's income in Eth. Birr: it is the continuous explanatory variable measured in (Eth. Birr). Household income is expected to have a positive and significant association with households' perception level. Because, as farm households have better income, they can search information, and enhance their knowledge and perception. As a result, in this study farm household's income and their perception towards agricultural extension are expected to associate positively and significantly. It is supported by the study result of Deressa, *et. al.,* (2011) that farm households' income and climate change perception (proxy predictor for extension perception) showed positive and significant relationship.

DA office distance (Km): it is a continuous explanatory variable measured in (Km) expected to influence farm households' perception intensity towards agricultural extension service. When farm households are far away from DA office, they are expected to miss frequent information access. Hence, their perception towards agricultural extension service expected to be low. As a result, in this study, farm households away from DA office and their perception towards agricultural extension service are hypothesized to correlate negatively and significantly. In the study of Ndambiri, *et. al.*, (2012), the distance of farmers from input output market/a proxy predictor for DA Office distance and farm households' perception on climate change showed negative and significant correlation.

Household's head sex: it is a non-continuous variable that takes the value of (1), when the farm household head is male; (0), otherwise. males are more familiar and have better exposure to external environment and have wider communication outside their household members. As a result, the male farm household heads' and their perception intensity are expected to correlate positively and significantly. In the study of Kisauzi, *et. al.*, (2012) female farm households access to extension showed significant limitation than male. Hence female access to extension and their perception towards climate change showed negative correlation. In addition, in the study of Komba, *et. al.,* (2018), on decentralization extension effectiveness, which correlated negatively with females' perception.

Households access to agricultural extension service: it is a non-continuous explanatory variable, expected to affect the farm household's perception intensity towards agricultural extension service. The variable takes the value (1) when the farm households have access to agricultural extension service; (0), otherwise. It is believed that farm households who have access to agricultural extension service can have better perception towards agricultural extension service. As a result, access to agricultural extension service help farm households to have better perception towards agricultural extension service. Hence, in this study, access to agricultural extension service and farm household's income status are hypothesized to associate positively and significantly. It is supported by the study of Elias, *et. al.,* (2015).

Household's participation in improved livestock production: it is a non-continuous explanatory variable expected to affect farm HH's perception intensity towards agricultural extension service. Participation in improved livestock production takes the value (1) for participants, and (0) for non-participants. Farm households who have participated in improved livestock production are expected to take information on their improved livestock and are expected to have better information and perception towards agricultural extension service. As a result, in this study, farm household's perception intensity towards agricultural extension service and their participation in improved livestock production (a proxy variable for households' wealth status) are expected to associate positively and significantly. Members of farm households which are relatively well-off are likely to purchase and use improved technologies, which help them to have better perception towards agricultural extension service (Kanwal, *et. al.,* 2016).

Household's off-farm participation: it is a non-continuous explanatory variable expected to affect farm HHs' perception towards extension service positively and significantly. It can take the value (1), when farm household participated in off-farm activities; otherwise (0). Farm households who have participated in off-farm activities are expected to have better income that can help them to buy and use improved agricultural technologies. When the farm households participated in off-farm activity, they seek information and advice from DAs, thereby, are expected to have better perception towards agricultural extension, which is supported by the study of Elias, *et. al.,* (2015) that farmers' satisfaction with extension service (a proxy variable for farmers' perception towards extension service in this study) showed a positive and significant correlation with off-farm income.

Household's participation in barley value addition practices: it is a non-continuous explanatory variable expected to affect farm households' perception level towards extension service. It takers the value of (1), when farm households are participated in barley value addition practices; (0) otherwise. Participation in value addition practices (barley value additions in this case) can enhance the farm households' perception towards agricultural extension service. It is because farm households are expected to consult DAs regarding the value addition practices. As a result, farm households are expected to get extension service on their value addition practices. Hence, participation in value addition practices and the farm households' perception intensity towards agricultural extension service are presumed to have positive and significant association, which supported by the study of Kanwal, *et. al.,* (2016) that the proximity to the nearest city (a proxy variable for the farm households' participation in value addition practices) showed significant and positive correlation with non-farm income diversification that help farm households to enhance their income status.

Annex 1.5. Description of predictors used in the analysis of farm households' aggregate income status (20 predictors with 7 continuous and 13 non-continuous predictors)

Household head age: it is the continuous explanatory variable measured in years. HHs head age and their income status are expected to associate negatively with the assumption that as farm household head's age increases, her/his participation in income generating activities decreased. Hence, in this study, the household head age and the household's income status are presumed to associate negatively and significantly. It is supported by the study of Onyeiwu and Liu (2011); and by Duniya and Rekwot (2015) that age and household's income correlate negatively.

Household head formal education in years of schooling: it is a continuous explanatory variable measured in years of schooling. The household head who has formal education is expected to use his/her education to analyze the information and use it to improve the income status of the household. As a result, in this study, the household head education and income status are expected to associate positively and significantly. Education of the household head was significant at 10% level and, its coefficient had a positive sign. Higher education level found in the study of Cuddya, *et. al.,* (2008) important to raise farm households' income. Furthermore, it is also confirmed in the study of (Fadipe, *et. al.,* 2014; Escobal, 2001; Wouterse and Taylor, 2008). In the study of Lazarus (2013), household head education and income from crop and non-farm work showed positive and significant correlation. Education level of the household heads was significant and positively influenced income diversification, and thereby, improve their income status according to, Kanwal, *et. al.,* (2016).

Household's size in Adult Equivalent: it is the continuous explanatory variable measured in adult equivalent. There is an assumption that, when the household size increase, the income demand also increased as a result of households' increased expenditure. In this study, farm household size and its income status are assumed to correlate negatively and significantly. However, the study conducted by Talukder (2014) in Bangladesh to assess Determinants of Income of Rural Households showed that households size and income correlated positively and significantly; and similarly, the study conducted by Lazarus (2013) in Mali, household size and income of the farm households' showed positive and significant correlation.

Household's Livestock size in TLU: it is the continuous explanatory variable measured in (TLU). Livestock are one source of income for farm HHs. As a result, HHs with high livestock size are expected to have better income status. Hence, in this study, livestock size and HHs' income status are expected to associate positively and significantly. It is supported by the study of Onyeiwu and Liu (2011) conducted in Keneya showed that livestock ownership such as sheep and oxen for plough and households' income status correlated positively and significantly. However ever, Livestock was negatively correlated with non-farm income diversification. Livestock is among the productive assets which are mostly agricultural and can be seen as proxies for socio-economic group or wealth. Members of farm households which are relatively well-off are likely to participate in non-farm jobs but when they do, they spend relatively less time in this activity. As a result, households' income reduced, Kanwal, *et. al.,* (2016).

Household's farm land size (Ha): it is a continuous explanatory variable measured in (Ha). Farm land is the major source of farm household's income. Hence, farm households with large farm size are expected to have better income status. Therefore, in this study, farm land size and household's income status are hypothesized to associate positively and significantly. It is supported by the study of Fadipe, *et. al.,* (2014); Ibekwe, (2010); Adebayo (1985); Cuddya, *et. al.,* (2008); Tuyen (2015); Talukder (2014).

Household's home distance from market (Km): it is a continuous explanatory variable measured in (Km). Market is considered as the source for various incomes and information to access to different income generating activities. However, when the farm household is far from market, it is expected to lose to participate in different income generating activities and information how and where to get income. Hence, farm household's income is expected to decrease. Therefore, in this study, market distance and household's income status are presumed to correlate negatively and significantly. It is supported by the study of Cuddya, *et. al.,* (2008) that farm households closer to large city are better in their income status than far farm households. The study by Lazarus (2013) in Mali showed that easy road access and households' non-farm income showed positive and significant correlation. Proximity to the nearest city showed significant and positive correlation with non-farm income diversification to enhance their income status, according to Kanwal, *et. al.,* (2016).

Household aggregate food availability(Kcal): it is a continuous explanatory variable measured in (Kcal). Total food availability is part of household's income. If the household has adequate income, its effort can be to involve in other activities that help to increase the household's aggregate income. In this study, the household's aggregate food availability and aggregate income are expected to correlate positively and significantly. As a result, farm households' food availability status (proxy variable for food intensity) and income from barley were expected to associate positively and significantly, supported by the study results of Kidane (2001); Degnet, *et al.,* (2001) and Getahun (2004), which all showed that households with better economy can adopt technologies, thereby, adequate food supply.

Household's head sex: it is a non-continuous explanatory variable has the dichotomous nature that takes (1) for the male household head and (0) when the farm household is headed by female household head. The household head (being male or female) matters the income status of households. Households' headed by male are expected to have better income status than female headed households. It is because, male is better in social linkage and information access due to the cultural and social settings. Therefore, male is expected to use their social linkage and networks as well as information they access to enhance their and their household member's income status. Therefore, in this study, male headed households and household's income are expected to associate positively and significantly as opposed to female headed households, which was supported by the study of Fadipe, *et. al.*, (2014) that the coefficient of explanatory variable, household head sex and income of the households showed negative and significant correlation. In addition, it was supported by the study of Onyeiwu and Liu (2011) that the proportion of female family members has a downward effect on household income. However, contrary to these, the study by Lhing, *et. al.*, (2013) showed that, gender/sex, male headed household members showed the increasing effect on HH' income.

Households' fertilizer adoption: it is the non-continuous explanatory variable having the dichotomous nature that takes the value (1) for adopters; and (0) for non-adopters of fertilizer. Using fertilizer in agricultural production can increase the yield of farm households. As a result, in this study, adoption of fertilizer and household's aggregate income status are hypothesized to have positive and significant association. Gains from new agricultural technology have influenced the poor directly, by raising incomes of farm households, and indirectly, by raising employment, wage rates of functionally landless laborers, and by lowering the price of food staples (Pinstrup-Andersen, *et. al.,* 1976).

Household's adoption of compost: it is the non-continuous explanatory variable having the dichotomous nature that takes in this study the value of (1) for compost adopters; and (0) for non-adopters. Using compost can increase agricultural crops yield, thereby, can improve the household's aggregate income. As a result, in this study, compost adoption and aggregate household income status are hypothesized to have a positive and significant association. Hence, compost adoption and intensity of income showed positive and significant association in the study of Hossain, *et. al.,* (1994).

Household's weedicide adoption: it is the non-continuous variable having the dichotomous nature that takes the value of (1) for weedicide adopters; and (0) for non-adopters. Weedicide is important agricultural input to increase agricultural crop yield by controlling the yield decreasing weeds. Therefore, using weedicide, in this study is hypothesized to improve the aggregate income status of the adopter farm households. Hence, in this study, weedicide adoption and adopter farm HHs' aggregate income status are presumed to associate positively and significantly. In this study, weedicide adoption and adopter farm household's intensity of income from barley are presumed to associate positively and significantly (Winters, *et. al.,* 1998).

Household's adoption of frequent plow: it is the non-continuous variable having the dichotomous nature that in this study it takes the value (1) for 3 and above times farm land plow adopters; and (0) for non-adopters. Farm households' who frequently plow their farm land are expected to increase their production, thereby, their aggregate income status. Therefore, frequent plow adoption and household's aggregate income status are hypothesized to have a positive and significant association. It is supported by the study of (Irz, *et. al.,* 2001).

Household's adoption of frequent weeding: it is the non-continuous explanatory variable in farm households' food availability status study. The variable has the dichotomous nature that takes the value (1) for two and above times weeding practice; and (0) for non-adopters. Farm households who frequently weed their crop, are expected to increase their production that increase/enhance their aggregate income status. Hence, in this study, frequent weeding practice and farm household's income are hypothesized to have a positive and significant association. It is supported by the study of (de Janvry and Sadoulet, 2001).

Household's adoption of improved seed: it is the non-continuous explanatory variable expected to affect farm household's aggregate income status. Improved seed are assumed to increase farm yield, and thereby, household's income status. In this study, farm households who adopt improved barley seed are expected to have better income status. The variable has the dichotomous nature that takes the value (1) for improved barley seed adopters; and (0) for non-adopters. Hence, in this study, improved barley seed adoption and HHs' income status is hypothesized to correlate positively and significantly. It is supported by the study of Mendola (2007), adopters of HYVs (high yielding varieties) seem to be better off than non-adopters, in that, average gross income of adopters is much higher than non-adopters and, taking into account only crop income, it is more than twice the income of non-adopters.

Household's adoption of farm drainage: it is the non-continuous explanatory variable in farm households' income status study. Farm households with better income status are expected to involve in practice of farm land drainage. The variable has the dichotomous nature that takes the value (1) for participation in farm land drainage; and (0) for non-adopters. Hence, farm land drainage practice and adopter farm household's aggregate income status are hypothesized to have positive and significant association. It is supported by the study finding of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's access to formal credit: it is a non-continuous explanatory variable, take the value (1), when the household has access to formal credit; (0), otherwise. Credit access has expected to improve the household's income status by alleviating the financial constraints to invest on income generating enterprises or activities. Therefore, in this study, credit access and household's income status are expected to associate positively and significantly. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's off-farm participation: it is a non-continuous explanatory variable expected to affect farm households' income status positively and significantly. It can take the value (1), when the farm household has participated in off-farm activities; otherwise (0). There is a general agreement that participation in off-farm activities can increase the household's income. As a result, households who participated in off-farm activity in addition to their main activity, they are expected to get additional income. Hence, participation in off-farm income and farm household's income status are expected to associate positively and significantly. It is supported by the study Cuddya, *et. al.*, (2008) that farm households' participated in off-farm work are better in their income than non-participants.

Household's access to agricultural extension service: it is a non-continuous explanatory variable, expected to affect farm household's income status positively and significantly. It is because, extension is considered as source of information and improved technologies as well as improved practices. Therefore, farm households who have access to agricultural extension service are expected to have better income status. Hence, in this study, access to agricultural extension service and farm household's income status are hypothesized to associate positively and significantly. It is supported by the study of Duniya and Rekwot (2015) that showed extension contact and household income correlated positively and significantly.

Household's participation in improved livestock production: it is a non-continuous explanatory variable expected to affect farm household's income status positively and significantly. Participation in improved livestock production takes the value (1) for participants, and (0) for non-participants. Farm households who have participated in improved livestock production are expected to have better income since they are expected better income from their improved livestock. In this study, farm household's participation in improved livestock production and household's income status are expected to associate positively and significantly.

Household's participation in barley output market options: it is a non-continuous explanatory variable having the categorical values (0) for non-participation, (1) for participation in one selling option, (2) in two, and (3) participation in three and more barley selling options. Availability of different barley selling options can give better option farm households to sell their barley output with better price that help to increase farm household's income status. Hence, in this study farm household's participation in different barley selling options and income status of the farm households are hypothesized to associate positively and significantly. According to Tigist (2017), markets open the opportunity to farm households to sell farm outputs, which help them to buy and use improved inputs and to tap a range of public and private services such as extension and credit access, which all help the farm households to remain economically self-sufficient and maintain food security.

Annex 1.6. Predictors' description used in the analysis of farm households' aggregate income intensity in Eth. Birr (20 predictors with 6 continuous and 14 non-continuous predictors)

Household head age: it is the continuous explanatory variable measured in years. The household head age and the households' income intensity are expected to associate negatively with the assumption that as farm household head's age increases, her/his participation in income generating activities decreased. Hence, in this study, the household head age and the household's income intensity are presumed to associate negatively and significantly. It is supported by the study of Onyeiwu and Liu (2011); Duniya and Rekwot (2015) that age and household's income correlate negatively.

Household head formal education in years of schooling: it is a continuous explanatory variable measured in years of schooling. The household head who has formal education is expected to use his/her education to analyze the information and use it to improve income. As a result, in this study, the household head education and income intensity are expected to associate positively and significantly. Education of the household head was significant at 10% level and, its coefficient had a positive sign. Higher education level found in the study of Cuddya, *et. al*., (2008) important to raise farm households' income. Furthermore, it is also confirmed in the study of (Fadipe, *et. al.,* 2014; Escobal, 2001; Wouterse and Taylor, 2008). In the study of Lazarus (2013), household head education and income from crop and non-farm work showed positive and significant correlation. Education level of the household heads was significant and positively influenced income diversification, and thereby, improve their income status according to, Kanwal, *et. al.,* (2016).

Household's size in Adult Equivalent: it is the continuous explanatory variable measured in adult equivalent. There is an assumption that, when the household's size increase, the income demand for the household also increased, which again increases the household's income expenditure that reduce the income intensity of the household. Therefore, in this study, farm household size and its income status are assumed to correlate negative and significantly. However, the study conducted by Talukder (2014) in Bangladesh to assess Determinants of Income of Rural Households showed that households size and income correlated positively and significantly; and similarly, the study conducted by Lazarus (2013) in Mali, household size and income of the farm households' showed positive and significant correlation.

Household's Livestock size in (TLU): it is the continuous variable measured in (TLU). Livestock is one source of income for farm households. Households with high livestock size are expected to have better income intensity. Therefore, in this study, livestock size and household's income intensity are expected to associate positively and significantly. It is supported by the study of Onyeiwu and Liu (2011) conducted in Keneya showed that livestock ownership such as sheep and oxen and households' income status correlated positively and significantly. However, Livestock was negatively correlated with non-farm income diversification. Livestock is among the productive assets and can be seen as proxies for socio-economic group or wealth. Members of farm households which are relatively well-off are likely to participate in non-farm jobs but when they do, they spend relatively less time in this activity. As a result, households' income reduced, Kanwal, *et. al.,* (2016).

Household's farm land size (Ha): it is a continuous explanatory variable measured in (Ha). Farm land is the major source of farm household's income intensity. Hence, farm households with large farm size are expected to have better income intensity. In this study, farm land size and household's income intensity are hypothesized to associate positively and significantly. It is supported by the study of Fadipe, *et. al.,* (2014); Ibekwe, (2010); Adebayo (1985); Cuddya, *et. al.,* (2008); Tuyen (2015); Talukder (2014).

Household's home distance from market (Km): it is a continuous explanatory variable measured in (Km). Market is considered as income source and information to access to different income generating activities. However, when the farm household is far from market, it is expected that the farm households may miss to participate in different income generating activities and information how and where to get income. Hence, farm household's income is expected to decrease. Therefore, in this study, market distance and household's income intensity are presumed to correlate negatively and significantly. It is supported by the study of Cuddya, *et. al.,* (2008) that households' proximity to a large city are better in their income status than far farm households. The study by Lazarus (2013) in Mali showed that easy road access and households' non-farm income showed positive and significant correlation. Proximity to the nearest city showed significant and positive correlation with non-farm income diversification to enhance their income status, according to Kanwal, *et. al.,* (2016).

Household's head sex: it is a non-continuous and dichotomous explanatory variable with the value (1) for male and (0) for female headed farm households. The household head (being male or female) matters the income intensity of households. Households' headed by male are expected to have better income intensity than female headed households. It is because, male is better in social linkage and information access due to the cultural and social settings that give more opportunities for male headed households. In this study, household head's sex and his/her income intensity are expected to associate positively and significantly. In the study of Fadipe, *et. al.,* (2014), the coefficient of explanatory variable, household head sex and income of the households showed negative and significant correlation, which indicates that the total household income was higher for male-headed households than female-headed ones. In addition, in the study of Onyeiwu and Liu (2011), the higher proportion of female family members has a downward effect on household income, while in the study by Lhing, *et. al.,* (2013), gender/sex and households' income showed positive and significant correlation.

Households' fertilizer adoption: it is the non-continuous explanatory variable having the dichotomous nature that takes the value (1) for adopters; and (0) for non-adopters of fertilizer. Using fertilizer in agricultural production can increase the yield of farm households. As a result, in this study, adoption of fertilizer and household's aggregate income intensity are hypothesized to have positive and significant association. Gains from new agricultural technology have influenced the poor directly, by raising incomes of farm households, and indirectly, by raising employment, wage rates of functionally landless laborers, and by lowering the price of food staples (Pinstrup-Andersen, *et. al.,* 1976).

Household's adoption of compost: it is the non-continuous explanatory variable having the dichotomous nature that takes in this study the value of (1) for compost adopters; and (0) for non-adopters. Using compost can increase agricultural crops yield, thereby, can improve the household's aggregate income intensity. As a result, in this study, compost adoption and aggregate household income intensity are hypothesized to have a positive and significant association. Hence, compost adoption and intensity of income showed positive and significant association in the study of Hossain, *et. al.,* (1994).

Household's weedicide adoption: it is the non-continuous variable having the dichotomous nature that it takes the value of (1) for weedicide adopters; and (0) for non-adopters. Weedicide is important agricultural input to increase agricultural crop yield by controlling the yield decreasing weeds. Therefore, using weedicide is hypothesized to improve the aggregate income intensity of the adopter farm households. Hence, in this study, weedicide adoption and adopter farm household's aggregate income intensity are presumed to associate positively and significantly. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of frequent plow: it is the non-continuous variable having the dichotomous nature that takes the value (1) for 3 and above times farm land plow adopters; and (0) for non-adopters. Farm households' who frequently plow their farm land are expected to increase their production, thereby, their aggregate income intensity. Therefore, frequent plow adoption and household's aggregate income intensity are hypothesized to have a positive and significant association. Hence, compost adoption and intensity of income showed positive and significant association in the study of Hossain, *et. al.*, (1994).

Household's adoption of frequent weeding: it is the non-continuous explanatory variable in farm households' aggregate income intensity. It is dichotomous that takes the value (1) for two/above times weeding practice; and (0) for non-adopters. Farm households who frequently weed their crop, are expected to increase their production that increase/enhance household's aggregate income intensity. Hence, in this study, frequent weeding practice and farm household's income are hypothesized to have a positive and significant association. In this study, weedicide adoption and adopter farm household's intensity of income from barley are presumed to associate positively and significantly (Winters, *et. al.*, 1998).

Household's adoption of improved seed: it is the non-continuous explanatory variable expected to affect farm household's aggregate income intensity. The variable has the dichotomous nature that takes the value (1) for improved barley seed adopters; and (0) for non-adopters. Improved seed are assumed to increase farm yield, and thereby, household's income intensity. In this study, farm households who adopt improved barley seed are expected to have better income intensity. Hence, improved barley seed adopters and farm household's income intensity are hypothesized to have a positive and significant association. It is supported by the study of Mendola (2007), adopters of HYVs (high yielding varieties) seem to be better off than non-adopters, in that, average gross income of adopters is much higher than non-adopters and, taking into account only crop income, it is more than twice the income of non-adopters.

Household's adoption of farm drainage: it is the non-continuous explanatory variable in farm households' food availability status study. Farm households with better income status are expected to involve in practice of farm land drainage. The variable has the dichotomous nature that takes the value (1) for participation in farm land drainage; and (0) for non-adopters. Hence, farm land drainage practice and adopter farm household's aggregate income intensity are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's access to formal credit: it is a non-continuous explanatory variable, take the value (1), when the household has access to formal credit; (0), otherwise. Credit access has expected to improve the household's income intensity by alleviating the financial constraints to invest on income generating enterprises or activities. Therefore, in this study, credit access and household's income intensity are expected to associate positively and significantly. According to Hussien and Janekarnkij, (2013), households' credit access affected households' food security. It is a study that credit access has a positive effect on food security (Wali and Janekarnkij, 2015; Demeke, 2011; Bogale and Shimelis, 2009).

Household's off-farm participation: it is a non-continuous explanatory variable expected to affect farm households' income intensity takes the value (1), when the farm household has participated in off-farm work; otherwise (0). There is a general agreement that participation in off-farm activities can increase the household's income intensity. As a result, households who participated in off-farm activity in addition to their main activity, they are expected to get additional income. Hence, participation in off-farm income and farm household's income intensity are expected to associate positively and significantly. It is supported by the study

Cuddya, *et. al.,* (2008) that farm households' participated in off-farm work are better in their income than non-participants.

Household's participation in barley output market options: it is a non-continuous explanatory variable having the categorical values (0) for non-participation, (1) for participation in one selling option, (2) in two barley selling options, and (3) participation in three and more barley selling options. Availability of different barley selling options can give better option for farm households to sell their barley output with better price that help to increase their income intensity. Hence, in this study farm household's participation in different barley selling options and income intensity are hypothesized to associate positively and significantly. According to Tigist (2017), markets open the opportunity to farm households to sell farm outputs that help them to buy improved inputs and tapa range of public and private services such as extension and credit access service, which help them to remain economically self-sufficient and maintain food security. In addition, the study by Olwande and Mathenge (2011) showed that participants in farm output market abled to exit from poverty as compared to non-participants in Kenya.

Household's access to barley extension service: it is a non-continuous explanatory variable, expected to affect the farm household's income intensity positively and significantly. It is because, extension is considered as source of information and source of improved technologies and practices. Therefore, farm households who have access to extension service to improve their barley production are expected to have better income intensity. Hence, in this study, access to extension service to enhance barley production and farm HH's income intensity are hypothesized to associate positively and significantly. It is supported by the study of Duniya and Rekwot (2015) that showed extension contact and HHs' income correlated positively and significantly.

Household's participation in improved livestock production: it is a non-continuous explanatory variable expected to affect farm household's income intensity positively and significantly. Participation in improved livestock production takes the value (1) for participants, and (0) for non-participants. Farm households who have participated in improved livestock production are expected to have better income intensity, since they may get better income from their improved livestock. Hence, farm household's participation in improved livestock production and household's income intensity are expected to associate positively and significantly, which supported by the study of Kanwal, *et. al.,* (2016) on the role of wealth to adopt improved technologies (proxy variable for households' participation in improved livestock production), which required high investment at household level.

Farm household's participation in Land Rent-in practice: it is the non-continuous explanatory variable that expected to influence farm HH' aggregate income intensity. The variable takes the value (1), when the farm HH is participated in farm land-rent-in practice; while (0) for non-participants. Renting farm land is a practice that help farm HHs' to increase their agricultural crop production, which help to enhance their aggregate income intensity. Therefore, farm households' participation in farm land rent-in practice and the intensity of their food availability from barley are hypothesized to associate positively and significantly. It is supported by the study of Hosaena and Stein (2012) that showed positive association between participation in land rent practice and food security in Ethiopia. Furthermore, Muraoka, *et. al.,* (2014) showed that land rent play a positive role in promoting household food security in rural Kenya.

Annex 1.7. Description of farm households' barley income intensity determinants (22 predictors with 7 continuous and 15 non-continuous predictors)

Household head age: it is the continuous explanatory variable measured in years. The household head age is expected to affect farm households' income intensity from barley in Eth. Birr. The assumption is that, when the farm household head's age increases, her/his participation in income generating activities decreased. Hence, in this study, household head age and income intensity from barley are presumed to associate negatively and significantly. It is supported by the study of Onyeiwu and Liu (2011); and by Duniya and Rekwot (2015) that age and household's income correlate negatively.

Household head formal education in years of schooling: it is a continuous explanatory variable measured in years of schooling. The household head who has formal education is expected to use his/her education to analyze the information and use it to improve the income intensity from barley. As a result, in this study, household head education and income intensity from barley are expected to associate positively and significantly. Higher education level found important to raise farm households' income in the study of Cuddya, *et. al.,* (2008), Fadipe, et. al., (2014); Escobal (2001), Wouterse and Taylor (2008), Lazarus (2013), Kanwal, *et. al.,* (2016).

Household's size in Adult Equivalent: it is the continuous explanatory variable measured in adult equivalent. There is an assumption that, when household's size increase, the income demand also increased, which again increases the household's income expenditure that reduce the income intensity of the household from barley. Therefore, in this study, farm household size and its income intensity from barley are assumed to correlate negatively and significantly. However, the study conducted by Talukder (2014) in Bangladesh to assess Determinants of Income of Rural Households showed household size and income correlated positively and significantly. The study conducted by Lazarus (2013) in Mali, showed that household size and their income showed positive and significant correlation.

Household's Livestock size in (TLU): it is the continuous explanatory variable measured in (TLU). Livestock are one source of income for farm households. As a result, households with high livestock size are expected to have better income intensity from barley. Therefore, in this study, livestock size and household's income intensity from barley are expected to associate positively and significantly. It is supported by the study of Onyeiwu and Liu (2011) conducted in Keneya showed that livestock ownership such as sheep and oxen for plough and households' income status correlated positively and significantly.

Household's farm land size (Ha): it is a continuous explanatory variable measured in (Ha). Farm land is the major source of household's income from barley. Hence, farm households with large farm size are expected to have better income intensity from barley. In this study, farm land size and household's income intensity from barley are hypothesized to associate positively and significantly. It is supported by the study of Fadipe, *et. al.,* (2014); Ibekwe, (2010); Adebayo (1985); Cuddya, *et. al.,* (2008); Tuyen (2015); Talukder (2014).

Household's home distance from market (Km): it is a continuous explanatory variable measured in (Km). Market is considered as the source for various incomes and information to access to different income generating activities. However, when the farm HH is far from market, it may miss opportunities to participate in different income generating activities and information how and where to get income. Hence, farm household's income from barley is expected to decrease. Therefore, in this study, market distance and household's income intensity from barley are presumed to correlate negatively and significantly. As shown in the study of Cuddya, *et. al.*, (2008), Lazarus (2013) in Mali, on road access and households' non-farm income, and in the study of Kanwal, *et. al.*, (2016) on the nearest city showed (proxy variable for market distance) showed significant and positive effect in enhancing farm households' income status.

Household aggregate food availability(Kcal): it is a continuous explanatory variable measured in (Kcal). Total food availability is part of the household's income, including income from barley. If the household has adequate income, it is expected to associate with farm household's intensity of income from barley positively and significantly. As a result, farm households' food availability status (proxy variable for food intensity) and income from barley were expected to associate positively and significantly, supported by the study results of Kidane (2001); Degnet, *et al.* (2001) and Getahun (2004), which all showed that households with better economy can adopt technologies, thereby, adequate food supply.

Household's head sex: it is a non-continuous (dichotomous) explanatory with the value (1) for the male household head and (0) for female headed households. The household head (being male or female) matters the income intensity of households. Households' headed by male are expected to have better income intensity than female headed households. It is because, male is better in social linkage and information access due to the cultural and social settings that give more opportunities for them. The household head, the variable's coefficient had a negative sign and was significant, which indicates household income was higher for male-headed households than female-headed ones (Fadipe, *et. al*., 2014; Onyeiwu and Liu 2011; Lhing, *et. al.*, 2013).

Households' fertilizer adoption: it is the non-continuous explanatory variable having the dichotomous nature that takes the value (1) for adopters; and (0) for non-adopters of fertilizer. Using fertilizer in barley production the farm households are expected to increase the yield of barley, thereby, the intensity of household's income from barley. As a result, in this study, adoption of fertilizer and household's intensity of income from barley are hypothesized to have a positive and significant association. Gains from new agricultural technology have influenced the poor directly, by raising incomes of farm households, and indirectly, by raising employment, wage rates of functionally landless laborers, and by lowering the price of food staples (Pinstrup-Andersen, *et. al.,* 1976).

Household's adoption of compost: it is the non-continuous explanatory variable having the dichotomous nature that takes in this study the value of (1) for compost adopters; and (0) for non-adopters. Using compost, farm households are expected to intensity of income from barley. As a result, in this study, compost adoption and intensity of income from barley are hypothesized to have a positive and significant association (Hossain, *et. al.,* 1994).

Household's weedicide adoption: it is the non-continuous variable having the dichotomous nature that takes the value of (1) for weedicide adopters; and (0) for non-adopters. Weedicide is an important agricultural input help to increase agricultural crop yield including barley crop yield, by controlling the yield decreasing weeds; and consequently farm HHs' aggregate and barley income. In this study, weedicide adoption and adopter farm household's intensity of income from barley are presumed to associate positively and significantly (Winters, *et.al.,* 1998).

Household's adoption of frequent plow: it is the non-continuous variable having the dichotomous nature that takes the value (1) for 3 and above times farm land plow practice adopters; and (0) for non-adopters. Farm households' who frequently plow their farm land are expected to increase their barley production, thereby, their intensity of income from barley. Therefore, frequent plow adoption and household's income intensity from barley are hypothesized to have a positive and significant association (*Irz, et. al.,* 2001).

Household's adoption of frequent weeding: it is the non-continuous explanatory variable in farm households' income intensity from barley. The variable has the dichotomous nature that takes the value (1) for two/above times weeding practice; and (0) for non-adopters. Farm households who frequently weed their barley crop, are expected to increase their production that increase/enhance their income intensity from barley. Hence, in this study, frequent weeding practice and farm household's income intensity from barley are hypothesized to have a positive and significant association (de Janvry and Sadoulet, 2001).

Household's adoption of improved seed: it is the non-continuous explanatory variable expected to affect farm HH's income intensity from barley. The variable has the dichotomous nature that takes the value (1) for improved barley seed adopters; and (0) for non-adopters. Improved seed are assumed to increase barley yield, and thereby, HH's income intensity from barley. In this study, farm HHs who adopt improved barley seed are expected to have better income intensity from barley. Hence, improved barley seed adoption and intensity of barley income are hypothesized to associate positively and significantly. It is supported by the study of Mendola (2007) that adopters of high yielding varieties seem to be better than non-adopters.

Household's adoption of farm drainage: it is the non-continuous explanatory variable in farm households' income intensity from barley. Participation in farm land drainage that has a problem of water logging is expected to increase yield and thereby income as a result of better yield from drained farm land crop production. The variable has the dichotomous nature that takes the value (1) for participation in farm land drainage; and (0) for non-adopters. Hence, farm land drainage practice and farm household's intensity of income from barley are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.,* (2003) that technology adoption is positively and significantly correlated with food security, which imply the likelihood of food security improvement.

Household's access to formal credit: it is a non-continuous explanatory variable in barley income intensity determinants analysis that takes the value (1), when the HH has access to formal credit; (0), otherwise. Credit access has expected to alleviate farm HH's improved technologies purchasing constraints. Hence, farm HHs who have credit access are expected to improve their income from their agricultural production including barley income intensity. Therefore, in this study, credit access and HH's income intensity from barley are expected to associate positively and significantly. According to Hussien and Janekarnkij, (2013), HHs' credit access affected HHs' food security. It is a study that credit access has a positive effect on food security (Wali and Janekarnkij, 2015; Demeke, 2011; Bogale and Shimelis, 2009).

Farm household's off-farm participation: it is a non-continuous explanatory variable expected to affect farm HHs' income intensity from barley. It can take the value (1), when the farm HH has participated in off-farm activities; otherwise (0). It is believed that participation in off-farm activities can increase farm HHs' income intensity from barley. As a result, HHs who participated in off-farm activity in addition to their main activity are expected to get additional income to enhance their agricultural production including barley, thereby, their income from barley. Hence, participation in off-farm and farm HH's barley income intensity are expected to associate positively and significantly. It is supported by the study Cuddya, *et. al.,* (2008) that farm HHs' participated in off-farm work are better in their income than non-participants.

Household's access to barley extension service: it is a non-continuous explanatory variable, expected to affect farm household's barley income intensity. Hence, extension is considered as source of information and improved technologies that help farm households' to increase their income from barley. Therefore, farm households who have access to extension service are expected to have better barley income intensity. Hence, in this study, access to extension service to enhance barley production and its income from barley are presumed to associate positively and significantly. It is supported by the study of Duniya and Rekwot (2015) that showed extension contact and household income correlated positively and significantly.

Farm household's participation in Land Rent-in practice: it is the non-continuous predictor expected to influence farm HHs' income intensity from barley. The variable takes the value (1), when farm HH has participated in farm land-rent-in; while (0) for non-participants. Renting farm land is a practice that help farm households to increase their agricultural crop production including barley production, which help to enhance their income intensity from barley. In this study, farm households' participation in farm land rent-in practice and the intensity of income from barley hypothesized to associate positively and significantly. It is supported by the study of Hosaena and Stein (2012) that showed positive association between participation in land rent practice and food security in Ethiopia. Furthermore, Muraoka, *et. al.,* (2014) showed that land rent play a positive role in promoting household food security in rural Kenya.

Farm household's participation in barley value addition practices: it is a non-continuous explanatory variable expected to affect farm households' intensity of income from barley. It takes the value of (1), when the farm households are participated in barley value addition practices; (0) otherwise. Participation in barley value addition practices can enhance the farm households' income from barley. When farm households participated in barley value addition practices, the households' income from barley can be improved. Therefore, participation in barley value addition practices and the intensity of income from barley, in this study are expected to correlate positively and significantly. Proximity to the nearest city (proxy variable for farm households' participation in barley value addition) help farm households income diversification, thereby, to enhance HHs' income (Kanwal, *et. al.,* 2016).

Farm household's income participation in irrigation production: it is the non-continuous explanatory variable, expected to affect farm households' intensity of income from barley. Participation in irrigation production including barley are expected to get additional barley crop yield that can enhance household's income from barley. Therefore, in this study, farm households' participation in irrigation production and income from barley are expected to correlate positively and significantly. Irrigation production played the significant role in enhancing the farm households' food security (a proxy variable for households' income) through yield improvement Sikwela (2008); Fanadzo (2012).

Farm households' participation in *Belg* production: it is the non-continuous explanatory variable, expected to affect farm households' intensity of income from barley positively and significantly. Participation in *Belg* (small rainy season) production helps farm households to get additional barley yield that can improve income from barley. Therefore, in this study, farm households' participation in *Belg* barley production their intensity of income from barley were hypothesized to correlate positively and significantly, which was supported by the study of Sikwela (2008) and Fanadzo (2012) conducted on the role of participation in irrigation production (a proxy for *Belg* production participation) in addition to the main season production which showed to improve households' income.

Annex 1.8. Predictors description used in farm households aggregate food availability status analysis (17 predictors with 7 continuous and 10 non-continuous predictors)

Household head age: it is a continuous variable expected to affect farm households' food availability status based on the threshold that, farm households with 2550 Kcal/per day/adult equivalent person (CSA and WFP, 2014). The house hold head age and household's food availability status are expected to associate negatively and significantly with the assumption that as age increases household's food availability is expected to decrease since the labor power of the old age people decreases to access food sources and secure their food requirements. It is supported by the study of Girma (2012); Fekadu (2012); Mannaf and Uddin (2012) that age and household food security showed negative correlation.

Household head formal education (years of schooling): it is the continuous variable expected to affect farm household's food availability status positively and significantly**.** It is because as farm household head education status increased, their information seeking and use of the information improve that help to increase farm household's food availability status. Farm household heads' education level in the study of Girma (2012) showed the positive relationship with food security (negative relationship with food insecurity). This result is consistent with the finding of Oluyole, *et. al.*, (2009).

Household size (Adult Equivalent): it is the continuous variable measured in adult equivalent that believed large household size required large quantity of food availability. Households' food availability status is determined based on the minimum quantity of food required for the household, based on 2550 Kcal/day/adult equivalent, according to CSA and WFP (2014). Hence, when the household is equal/above this minimum standard, the household is said to be food secure; otherwise, food insecure. Therefore, in this study, farm household size and household's food availability status are assumed to correlate negatively and significantly, which is supported by the study of Joshi and Joshi (2017); Misgna (2014); Hiwot (2014).

Household's Livestock size (TLU): it is the continuous variable, measured in (TLU). Households with better livestock size ownership is expected to be better in food availability status, because of that households with better livestock size can sell their livestock and cover their household members' food demand. Hence, it is believed that livestock size and their food availability status are expected to have positive association. Hence, as the ownership of the livestock size increases farm households' food availability is expected to increase, which is supported by the study result of Joshi and Joshi (2017) on household food security, trends and determinants in mountainous districts of Nepal that household's livestock ownership influence households' food security positively and significantly. In addition, in the study of Bogale and Shimelis (2009), Misgna (2014), (TLU)showed positive and significant relationship with food security status of the farm households.

Household's farm land size (Ha): it is a continuous variable measured in (Ha). When farm land size of the household is high, they can produce or rent-out with better price, which can give opportunity to them to have the required food amount for their household members. In this study, farm land size and household's food availability are hypothesized to associate positively and significantly with the assumption that as farm land size increases household's food availability showed to increase. In the study of Shiferaw, *et. al.,* (2003); Hiwot (2014); Haile (2005); Misgna (2014) farm land size and households' food security showed a positive and significant relationship implying that food security increases with farm size.

Household's income in Eth. Birr: the household's income in Eth. Birr is expected to have a positive and significant association with households' food availability status. Because, as farm households have better income, they can improve their food availability through buying and using improved technologies. As a result, the household's income and household's food availability status are expected to correlate positively and significantly. It is supported by the study of Bogale and Shimelis (2009) and by the study of Misgina (2014) that as farm households' income status increases, their food security status also showed to improve.

Household's home distance from market (Km): it is a continuous explanatory variable measured in (Km) that it is expected to affect farm households' aggregate food availability status. Market is considered as a place from which farm households can get information and access improved technologies and credit sources that all help farm households to enhance their agricultural production, thereby, their aggregate food availability status. As a result, in this study, farm households' aggregate food availability status and market distance presumed to associate negatively and significantly, which is supported by the study result of Joshi and Joshi (2017) on household food security, trends and determinants in mountainous districts of Nepal that the predictor distance to markets negatively influenced food security. addition, market distance and food security showed negative correlation with households' food security as confirmed in the study of Shiferaw, *et. al.*, (2003); Fekede, *et. al.*, (2016).

Household's head sex: it is the dichotomous variable that takes the value (1) for male and (0) for females. The household head gender (male/female) matters food availability. Households' headed by male are better in food availability than female headed. It is, due to cultural tradition, male households have better opportunity and social networks to secure their members food availability. Hence, in this study, male headed households' and their food availability status has expected to associate positively and significantly as opposed to female headed households, which means, the male headed households' food availability status is expected to be equal and above the minimum threshold (2550Kcal/day/adult equivalent); and the vice versa for female headed households. The gender of the household head showed positive and significant relationship with household's food security status. Households headed by female have higher probability of being food insecure (Amaza, *et. al.*, 2006).

Households' fertilizer adoption: it is the non-continuous variable having the dichotomous nature that in this study it takes the value (1) for adopters of fertilizer; and (0) for non-adopters. Using fertilizer can increase the yield of farm households. As a result, in this study, adoption of fertilizer and the food availability status of adopter farm households are hypothesized to have positive and significant association. In general technology adoption is positively and significantly related to the probability of food security as shown in the study of Shiferaw, *et. al.*, (2003). Furthermore, this result is also supported by the findings of Mulugeta (2002), Ramakrishna and Assefa (2002) and Ayalew (2003).

Household's adoption of compost: it is the non-continuous and dichotomous explanatory variable takes the value (1) for compost adopters; and (0) for non-adopters. Using compost can increase agricultural crops yield, thereby can improve the food availability of the farm households. As a result, in this study, compost adoption and food availability status of adopter farm households are hypothesized to have positive and significant association. It is supported by the study result of Shiferaw, *et. al.,* (2003) that technology adoption (a proxy variable for compost adoption) is positively and significantly related to food security, implying that compost adoption can improve farm households' food security.

Household's weedicide adoption: it is the non-continuous variable having the dichotomous nature that in this study it takes the value (1) for weedicide adopters; and (0) for non-adopters. Using weedicide to control the yield decreasing weeds can increase production. Therefore, using weedicide, in this study is hypothesized to improve the food availability status of adopter farm households. Hence, weedicide adoption and adopter farm household's food availability status are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.,* (2003) that technology adoption (a proxy variable for weedicide adoption) is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of frequent plow: it is the non-continuous variable having the dichotomous nature that in this study it takes the value (1) for frequent plow (3 and above times) adopters; and (0) for non-adopters. Farm households' who frequently plow their farm land are expected to increase their production, thereby, increase their food availability status. Therefore, frequent plow adoption and food availability status of adopter farm households are hypothesized to have positive and significant association. Therefore, frequent plow adoption and household's aggregate income status are hypothesized to have a positive and significant association. It is supported by the study of (Irz, *et. al.,* 2001).

Household's adoption of frequent weeding: it is the non-continuous and dichotomous explanatory variable that has expected to have positive and significant correlation with farm households' food availability status. The variable has the nature that takes the value (1) for frequent weeding practice (2 and above times) adopters; and (0) for non-adopters. Farm households who frequently weed their crop, are expected to increase their production that increase/enhance their food availability status. Hence, in this study, frequent weeding practice and food availability status of adopter farm households are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of improved seed: it is the non-continuous explanatory variable in farm households' food availability status study. In this study, farm HHs who adopt improved barley seed, their food availability status are expected to have positive and significant association. The variable has the dichotomous nature that takes the value (1) for improved barley seed adopters; and (0) for non-adopters. Hence, improved barley seed adopter farm households and their food availability status are hypothesized to have positive and significant association. In the study of Shiferaw, *et. al.*, (2003), adopters of improved seeds along with improved agronomic practices were more likely to be food secured than non-adopters. Furthermore, study by Ahmed (2015) showed that improved seed users were better in their food security status than non-users.

Household's adoption of farm drainage: it is the non-continuous explanatory variable in farm HHs' food availability status study. Farm HHs with better food availability status are expected to involve in frequent weeding. The variable has the dichotomous nature that takes the value (1) for frequent weeding practice (2 and above times) adopters; and (0) for non-adopters. Hence, frequent weeding practice and adopter farm HH's food availability status are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's access to formal credit: it is a non-continuous explanatory variable expected to affect farm household's food availability status positively and significantly. Farm households' access to formal credit can alleviate their financial constraint and help them to buy and use improved technologies that enhance productivity, thereby, households' food availability status. Therefore, farm household's credit access and their food availability status are expected to associate positively and significantly in this study. In the study of Hiot (2014); in Demeke (2011), and in and Tekle and Berhanu (2015) access to credit has the likelihood of increasing food security. Credit service in the study of Girma (2012) showed the negative relationship with food insecurity in that the household who have credit service have less chance to be food insecure than those without credit access.

Household's access to agricultural extension service: it is the non-continuous explanatory variable expected to affect farm households' aggregate food availability status. In this study, farm households with better extension service has hypothesized to affect farm household's food availability, positively and significantly. Extension service to the farming community are vital to disseminate relevant information and improved technologies that can enhance productivity and households' food availability. Hence, farm households who have better extension service access are expected to have better food availability status, which is supported by the study of Asogwa, *et. al.,* (2012) that extension service and food security correlated positively significantly.

Annex 1.9. Description of predictors affecting intensity of farm households' aggregate food availability in Kcal (19 predictors with 6 continuous and 13 non-continuous predictors)

Household head age (years): it is a continuous explanatory variable measured in Kcal. Household head age has expected to affect farm households' aggregate food availability intensity negatively. When the farm household heads age increases, household's food production expected to decreased. It is because, the household heads are most of the time responsible for the household members. Therefore, when the household head age increases, their production performance and their labor force decreases to fulfill the food demands of farm household. On the other hand, according to, the minimum food requirement per adult equivalent person per day 2550 Kcal (CSA and WFP, 2014). As a result, in this study, it is hypothesized that the age of farm household head and intensity of food availability are presumed to correlate negatively and significantly. However, in the study of Bogale and Shimelis (2009), household head age and food security showed positive relationship. The possible justification was given that as age of the household head increase the households acquired more and more experience in farming operations, thereby, wealth accumulation that protect farm households from being food insecure.

Household head formal education (years of schooling): it is the continuous explanatory variable measured in years. In this study, it is hypothesized that when the farm HH head's formal education in (years) has increased, his/her information seeking and analysis is expected to increase to fulfill the HHs' food demand. Therefore, the farm HH head formal education and the intensity of food availability are expected to increase. Hence, farm household head formal education and intensity of food availability are expected to associate positively and significantly. It is supported by the study of Ahmed, *et. al.,* (2015) that education and households' food security showed positive and significant correlation. This suggests that the level of formal education could impact positively and significantly the household production and nutrition decision thereby reducing food insecurity intensity. This result is consistent with the finding of Oluyole, *et. al.,* (2009).

Household size (Adult. equiv.): it is the continuous variable measured in adult equivalent. It is believed that large household size, required large quantity of food supply. In this study, the household size in (adult equivalent) and food availability intensity are expected to correlate negatively and significantly, which is supported by the study of Bogale and Shimelis (2009) that they concluded, family size and food security correlated negatively due to the fact that households depend on less productive agricultural land, hence, increasing household size resulted in increased demand for food. This demand, however, cannot be matched with the existing food supply, so ultimately end up with food insecurity.

Households' livestock ownership (TLU): it is the continuous variable, measured in (TLU) that hypothesized to correlate with farm household's aggregate food availability intensity positively and significantly. It is because, livestock is one major source of food and income. Therefore, households with better livestock size is expected to be better in food availability intensity, since they can sell their livestock and buy yield enhancing technologies. Hence, it is believed that livestock size and household's food availability intensity, in this study are expected to have positive and significant association, which is supported by the study of Bogale and Shimelis (2009), who showed the relationship between livestock holding in (TLU) and food insecurity turned out to be negative and statistically significant. This is an indication that ownership of livestock acts as a hedge against food insecurity. Livestock, besides its direct contribution to subsistence need and nutritional requirement, it is to crop production by providing manure, power for farming and accumulated wealth.

Farm land size (Ha): it is a continuous explanatory variable, measured in (Ha). Large farm land size of the households is expected to get more crop yield. Hence, it is expected to affect farm household's intensity of food availability. Therefore, in this study, farm land size and households' food availability intensity are presumed to associate positively and significantly. Cultivated land size was influence food insecurity negatively. The results of the logit model in the study of Bogale and Shimelis (2009) indicated that sample households which had larger farm size had less risk of being food insecure.

Household income (Eth. Birr): it is a continuous explanatory variable, measured in (Eth. Birr), hypothesized to correlate with farm HHs' food availability intensity positively and significantly. When the farm HHs have better income, they can invest on improved technologies, thereby, enhance their intensity of food availability. Therefore, in this study, farm HHs' income and their intensity of food availability are expected to correlate positively and significantly. It is because, as farm HHs have better income, they can improve their food availability intensity through investing on improved and yield enhancing technologies, which is supported by the study of Holden, *et.al.,* (2004), Bogale and Shimelis (2009); Misgina (2014) that, off farm activity has positive welfare implications. Hence, HHs, who have access to better income opportunities are less likely to become food insecure than those who had no or little access to income.

Households' fertilizer adoption: it is the non-continuous explanatory variable with dichotomous value that (1) represents for fertilizer adopters; and (0) for non-adopters. Fertilizer can increase the yield of farm households, thereby, their food availability intensity. As a result, in this study, adoption of fertilizer and aggregate food availability intensity are hypothesized to have positive and significant association. Fertilizer adoption and farm households' food security showed positive and significant correlation in the study of Wali and Janekarnkij (2015) that was conducted in Jigjiga District of Ethiopia; and in the study of Misgna (2014) conducted in Laelaymychew Woreda, Central Zone of Tigryi, Ethiopia;

Household's weedicide adoption: it is the non-continuous variable having the dichotomous nature takes the value (1) for weedicide adopters; and (0) for non-adopters. Using weedicide to control the yield decreasing weeds can increase production. Therefore, using weedicide, in this study is hypothesized to improve the food availability intensity of adopter farm HHs. Hence, weedicide adoption and adopter farm HH's food availability intensity are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.,* (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of improved agricultural technologies.

Farm household's adoption of compost: it is the non-continuous explanatory variable having the dichotomous nature that takes the value (1) for compost adopters; (0) for non-adopters. Compost using can increase crops yield, thereby, the intensity of food availability of the farm households. As a result, in this study, compost adoption and food availability intensity are hypothesized to have positive and significant association. It is supported by the study result of Shiferaw, *et. al.,* (2003) that technology adoption (a proxy variable for compost adoption) is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of frequent plow: it is the non-continuous variable having the dichotomous nature that in this study it takes the value (1) for frequent plow (3 and above times) adopters; and (0) for non-adopters. Farm households' who frequently plow their farm land are expected to increase their production, thereby, increase their intensity of food availability. Therefore, frequent plow adoption and food availability intensity adopter farm households are hypothesized to have positive and significant association. Therefore, frequent plow adoption and household's aggregate income status are hypothesized to have a positive and significant association. It is supported by the study of (Irz, *et. al.*, 2001).

Household's adoption of frequent weeding: it is the non-continuous explanatory variable expected to affect farm HHs' food availability intensity. The variable has the dichotomous nature that takes the value (1) for two or more frequent weeding adoption; and (0) for non-adopters. Farm HHs who frequently weed their crop are expected to increase their production that increase/enhance intensity of food availability. Hence, frequent weeding practice and intensity of food availability are hypothesized to correlate positively and significantly, in this study. It is supported by the study result of Shiferaw, *et. al.,* (2003) that technology adoption and is positively and significantly associated with food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of farm drainage: it is a non-continuous explanatory variable expected to affect farm households' food availability intensity. It has a dichotomous nature takes the value (1) for adoption of farm land drainage; and (0) for non-adopters. Farm households who have participated farm land drainage practices are expected to produce better agricultural crop including barley, by alleviating the water logging problem through farm land drainage practice. Therefore, farm households' participation in drainage practice and their food availability intensity are expected to associate positively and significantly. It is supported by the study of Shiferaw, *et. al.,* (2003) that technology adoption and food availability intensity is associated positively and significantly, which implying that the likelihood of food security increases with the use of improved agricultural technologies.

Household's adoption of improved seed: it is the non-continuous explanatory variable expected to affect farm households' intensity of food availability. The variable has the dichotomous nature that takes the value (1) for improved barley seed adopters; and (0) for non-adopters. Using improved seed is expected to improve the yield of agricultural crops. As a result, in this study, farm households who adopt improved barley seed and their food availability intensity are expected to have positive and significant association. In the study of Shiferaw, *et. al.,* (2003), adopters of improved seeds along with improved agronomic practices were more likely to be food secured than non-adopters. Furthermore, study by Ahmed (2015) showed that improved seed users were better in their food security status than non-users; and according to Shiferaw, *et. al.,* (2003), adopters of improved seeds along with improved agronomic practices are more likely to be food secure than non-adopters.

Household's access to formal credit: it is a non-continuous explanatory variable expected to affect farm household's food availability intensity positively and significantly. The variable takes the value (1), when the farm households have access to formal credit; (0) otherwise. Farm households' access to formal credit can alleviate their financial constraint and help them to buy and use improved agricultural technologies that enhance productivity, thereby, improve the intensity of households' food availability. Therefore, farm household's credit access and their food availability intensity are expected to associate positively and significantly in this study. It is a study that credit access has a positive effect on food security (Wali and Janekarnkij, 2015; Demeke, 2011; Bogale and Shimelis, 2009).

Household's access to agricultural extension service: it is the non-continuous explanatory variable that has expected to affect the intensity of farm households' food availability positively and significantly. It takes the value of (1), when farm households have access to extension service; (0) otherwise. Farm households who have better extension service are expected to have better food availability intensity. Agricultural extension service to the farming community are vital to disseminate relevant information and improved technologies that help them to enhance their agricultural productivity and intensity of food availability. The positive and significant correlation of extension service and households' intensity of food availability has supported by the study of Ahmed, *et. al.,* (2015), who concluded that extension agent contact and households' food security correlated positively and significantly, which suggested that extension agent contact is important in the adoption of modern farm practices that ultimately influences the level of farm output and income earning capacity of households, hence ensured food security of farm households in the study area.

Household's participation *Belg* production: it is the non-continuous and dichotomous explanatory variable, expected to affect farm HH' food availability intensity positively and significantly. Farm HHs who have participated in *Belg* (small rainy season) production can get additional crop yield to their main season production. In this study, farm HHs, who have participated in *Belg* crop production are represented by the value (1) and by (0) for non-participants. It is supported by the study of Bogale and Shimelis (2009) in irrigation production participation and HHs' food security that their study showed that participation in irrigation production (a proxy variable for HHs' participation in *Belg* production), which is additional production participation to the main production that can enhance households' food security.

Household's Land-rent-in participation: it is the non-continuous explanatory variable expected to influence farm household' food availability intensity positively and significantly. The variable takes the value (1), when the farm household is participated in farm land-rent-in practice; while (0) for non-participants. Renting farm land practice, help farm households to alleviate farm households' land scarcity, which help farm households to get additional agricultural production, thereby, to increase households' food availability. It is supported by the study of Hosaena and Stein (2012); and Muraoka, *et. al.*, (2014) that showed positive and significant association between participation in land rent practice and households' food security in Ethiopia and rural Kenya respectively.

Household's participation in barley selling options: it is a non-continuous explanatory variable having the categorical values (0) for non-participation, (1) for participation in one selling option, (2) in two, and (3) participation in three and more barley selling options. Availability of different barley selling options can give better option farm HHs to sell their barley output with better price that help to increase farm HH's income status. Hence, in this study farm HH's participation in different barley selling options and income status of the farm HHs are hypothesized to associate positively and significantly. According to Tigist (2017), markets open the opportunity to farm HHs to sell farm outputs, which help them to buy and use improved inputs and to tap a range of public and private services such as extension and credit access, which all help the farm households to remain economically self-sufficient and maintain food security. In addition, the study by Olwande and Mathenge (2011) showed that participants in farm output market abled to exit from poverty as compared to non-participants in Kenya.

Household's participation in barley value addition practices: it is a non-continuous explanatory variable expected to affect farm HHs' intensity of aggregate food availability. It takes the value (1), when farm HHs' are participated in barley value addition practices; (0) otherwise. Participation in value additions (barley value additions, in this case) can enhance the farm households' food availability. When farm households participated in value addition practices, the households' economic status can be improved. Then, they can invest on improved agricultural technologies that help them to enhance the intensity of their food availability. Therefore, participation in value addition practices and the intensity of farm households' food availability are presumed to have positive and significant association. Proximity to the nearest city help farm households to participate in activities that can bring income for the household (such as non-farm income) and value addition practices to increase their income gains thereby, their food supply through purchase or production through use of purchased inputs, which is the income diversification to enhance farm HHs' income (Kanwal, *et. al.,* 2016).

Annex 1.10. Description of predictors affecting the intensity of barley food availability (Kcal) at household level (20 predictors with 6 continuous and 14 non-continuous)

Household head age (years): it is a continuous explanatory variable measured in (Kcal). Household head age is expected to affect farm households' intensity of food availability from barley negatively and significantly. It is because, when the farm household heads age increases, household's production and participation in agricultural activities is assumed to decrease. Therefore, in this study, it is hypothesized that the age of farm household head and the food availability intensity from barley are presumed to correlate negatively and significantly. It is supported by the study of Girma (2012); Fekadu (2012); Mannaf and Uddin (2012) that age and household food security showed negative correlation.

Household head formal education (years of schooling): it is the continuous explanatory variable measured in years. In this study, it is hypothesized that when the farm HH head's formal education in (yrs) has increased, his/her information seeking and analysis and use of information is expected to increase that help them to increase their barley production, which again increase the intensity of food from barley. Therefore, in this study, farm HH head formal education and intensity of food availability from barley are expected to associate positively and significantly. The higher the educational level of a head of household is, the more food secure the household (Amaza, *et. al.,* 2006). This result also consistent with the finding of Oluyole, *et al,.* (2009).

Farm Land size (Ha):it is a continuous explanatory variable, measured in (Ha). Large farm land size is the source of more food for the farm HH's. It is expected that farm HH's with large farm land size are expected to produce and own high quantity of food crop. Hence, farm HH's with large barley farm land is expected to produce more barley crop that increase the intensity of food availability from barley. Therefore, in this study, farm land size and the intensity of food availability are presumed to associate positively and significantly. Households with larger farm sizes are more food secure than those with smaller sizes (Amaza, *et. al.,* 2006). There is a positive and significant correlation between farm land size and food security (Haile, *et.al.,* 2005).

Household size (Adult equivalent): it is the continuous explanatory variable measured in adult equivalent. It is believed that for large farm household size, high availability of food quantity is required. Barley food is part of food required for farm household in the study area. Hence, household size and the quantity of barley food are correlated negatively. In this study, farm household size and the intensity of barley food availability are hypothesized to associate negatively and significantly. Household size affect households' food security negatively and significantly. This shows that household with large sizes had higher possibility of being food insecure than those with smaller size (Amaza, *et. al.,* 2006). On the other hand, as the number of family in the household increases food security decreases as there are much more family who are going to share from the given yield or income (Hiwot, 2014).

Household Livestock size (TLU):it is the continuous explanatory variable, measured in (TLU) that hypothesized to affect farm household's intensity of food availability from barley. It is because, livestock is one major source of food and income. Farm households use oxen labor for plowing of barley farm land that increase barley yield, which in turn, contribute to increase the availability of food from barley. Therefore, households with better livestock size is expected to have better or high quantity of food availability from barley. Hence, it is believed that livestock size and household's intensity of food availability from barley are expected to have positive and significant association. The possession of greater numbers of livestock implies a higher likelihood of food security (Joshi and Joshi, 2017). In addition, in the study of Bogale and Shimelis (2009), Misgna (2014), (TLU) showed positive and significant relationship with food security status of the farm households.

Annual Income (Eth. Birr): it is a continuous explanatory variable, measured in (Eth. Birr) was hypothesized to associate with farm household's intensity of barley food availability positively and significantly. When farm households have better income, they can invest on improved agricultural technologies, thereby, enhance the intensity of barley food availability. Therefore, in this study, farm households' income and the intensity of barley food availability are hypothesized to associate positively and significantly. It is supported by the study of Bogale and Shimelis (2009); Misgina (2014) that they concluded, farm households' income status and their food security are correlated positively and significantly.

Household head sex: it is the non-continuous and dichotomous explanatory variable takes the value (1) for male and (0) for female households. The HH head gender (being male or female) matters the intensity of food availability from barley production. Households' headed by male are better in barley food availability intensity than female headed households. It is because, due to cultural tradition, male HHs have better opportunity and social networks that help them to secure their members food availability adequacy, in this barley food availability. Hence, the male headed HHs' and their barley food availability intensity has expected to associate positively and significantly as opposed to female headed HHs. Then, the male headed households' barley food availability intensity is expected to be equal/above the minimum threshold (2550Kcal/day/adult equivalent); and vice versa for female headed households. The gender of the household head showed positive and significant relationship with household's food security status. Households headed by female have higher probability of being food insecure (Amaza, *et. al.*, 2006).

Households' fertilizer adoption: it is the non-continuous explanatory variable having the dichotomous nature taking the value (1) for adopters of fertilizer; and (0) for non-adopters. Using fertilizer can increase the yield of farm households, thereby, the intensity of food availability from barley. As a result, in this study, adoption of fertilizer and the intensity of barley food availability are hypothesized to have positive and significant association. According to, Hussien and Janekarnkij (2013), fertilizer use has affected food security of households positively. In general technology adoption is positively and significantly correlated with food security as shown in the study of Shiferaw, *et. al.,* (2003); in Mulugeta (2002), Ramakrishna and Assefa (2002); and in the study of Ayalew (2003).

Household's adoption of compost: it is the non-continuous explanatory variable having the dichotomous nature that takes the value (1) for compost adopters; (0) for non-adopters. Compost using can increase barley crops yield, thereby, the intensity of food availability of the farm households from barley. As a result, in this study, compost adoption and farm households' food availability intensity from barley are hypothesized to have positive and significant association. Hence, compost adoption and intensity of income showed positive and significant association in the study of Hossain, *et. al.*, (1994).

Farm household's weedicide adoption: it is the non-continuous explanatory variable having the dichotomous nature takes the value (1) for weedicide adopters; and (0) for non-adopters. Using weedicide to control the yield decreasing weeds, it is possible to increase barley crop yield. Therefore, using weedicide, in this study, is hypothesized to improve the barley food availability intensity of adopter farm households. Hence, weedicide adoption and adopter farm household's barley food availability intensity are hypothesized to have positive and significant association. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of frequent plow: it is the non-continuous explanatory variable having the dichotomous nature takes the value (1) for frequent plow (3 and above times) adopters; and (0) for non-adopters. Farm households' who frequently plow their farm land are expected to increase their barley production, thereby, increase their intensity of barley food availability. Therefore, frequent plow adoption and barley food availability intensity of adopter farm households are hypothesized to have positive and significant association. Therefore, frequent plow adoption and household's aggregate income status are hypothesized to have a positive and significant association. It is supported by the study of (Irz, *et. al.*, 2001).

Farm household's adoption of frequent weeding: it is the non-continuous explanatory variable expected to affect farm HH's barley food availability intensity. The variable has the dichotomous nature that takes the value (1) for two or more frequent hand weeding adoption; and (0) for non-adopters. The adopters are expected to increase their production that increase/enhance their barley food availability intensity. Hence, in this study, frequent weeding practice and intensity of barley food availability of adopter farm households are hypothesized to correlate a positive and significant association. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly associated with food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Household's adoption of improved seed: it is the non-continuous explanatory variable expected to affect farm households' intensity of barley food availability. The variable has the dichotomous nature that takes the value (1) for improved barley seed adopters; and (0) for non-adopters. Using improved seed is expected to improve the yield of barley crops. As a result, in this study, farm households who adopt improved barley seed and their barley food availability intensity are expected to have positive and significant association. In the study of Shiferaw, *et. al.,* (2003), adopters of improved seeds along with improved agronomic practices were more likely to be food secured than non-adopters. Furthermore, study by Ahmed (2015) showed that improved seed users were better in their food security status than non-users; and according to Shiferaw, *et. al.*, (2003), adopters of improved seeds along with improved agronomic practices are more likely to be food secure than non-adopters.

Household's adoption of farm drainage: it is a non-continuous explanatory variable expected to affect the farm HHs' barley food availability intensity. The variable is dichotomous that takes the value (1) for adoption of farm land drainage practice; and (0) for non-adopters. Farm HHs' who have participated farm land drainage practices are expected to produce better barley yield, by alleviating the water logging problem through farm land drainage practice. Therefore, farm households' participation in drainage practice and their barley food availability intensity are expected to associate positively and significantly. It is supported by the study of Shiferaw, *et. al.*, (2003) that technology adoption is positively and significantly related to food security, implying that the likelihood of food security increases with the farmers' use of agricultural technologies.

Farm house holds formal credit access: it is a non-continuous explanatory variable expected to affect farm HH's barley food availability. The variable takes the value (1), when farm HHs have access to formal credit; (0) otherwise. Farm HHs' access to formal credit can alleviate their financial constraint to buy and use improved agricultural technologies that enhance barley productivity, thereby, improve the intensity of barley food availability. Therefore, in this study, farm HH's credit access and their barley food availability intensity are expected to associate positively and significantly. According to Hussien and Janekarnkij, (2013), HHs' credit access affected HHs' food security. It is a study that credit access has a positive effect on food security (Wali and Janekarnkij, 2015; Demeke, 2011; Bogale and Shimelis, 2009).

Farm households' access to barley extension service: it is the non-continuous explanatory variable that has expected to affect the intensity of farm households' barley food availability. It takes the value of (1), when farm households have access to extension service; (0) otherwise. Access to extension service help farm households to improve the intensity of barley food availability. Therefore, farm household's intensity of food availability from barley and access to extension service are presumed to correlate positively and significantly. Households that had access to extension agents have higher probability of being food secure than those have not access to extension agent and vice versa. This is because access to extension agents enhances the chances of households having access to better crop production techniques improved input as well as other production incentives and these affect their output vis-à-vis their food security status (Amaza, *et. al.,* 2006; Hussien and Janekarnkij, 2013).

Household participation in barley selling options: it is a non-continuous explanatory variable having the categorical values (0) for non-participation, (1) for participation in one selling option, (2) in two, and (3) in three and more barley selling options. Availability of different barley selling options can give better option for farm HHs to sell their barley output with better price that help to increase barley production and intensity of barley food availability. Hence, in this study, farm HH's participation in barley selling options and intensity of food availability from barley are hypothesized to associate positively and significantly. According to Tigist (2017), markets open the opportunity to farm HHs to sell farm outputs, which help them to buy and use improved inputs and to tap a range of public and private services such as extension and credit access, which all help the farm HHs to remain economically self-sufficient and maintain food security. In addition, the study by Olwande and Mathenge (2011) showed that participants in farm output market abled to exit from poverty as compared to non-participants in Kenya.

Households participation in *Belg* production: it is the non-continuous explanatory variable, expected to affect farm households' intensity of food availability from barley. Farm households who have participated in *Belg* (small rainy season) production can get additional barley crop yield in addition to barley crop yield from the main season production. Therefore, in this study, farm households, who have participated in *Belg* crop production and the intensity of food availability from barley are expected to correlate positively and significantly. It is supported by the study of Bogale and Shimelis (2009), participation in irrigation production (the proxy variable for *Belg* production), showed a statistically significant and negative relationship with food insecurity, which means positive and significant relationship with food security.

Farm household's participation in Land Rent-in practice: it is the non-continuous explanatory variable that expected to influence farm household' food availability intensity from barley. The variable takes the value (1), when the farm household is participated in farm land-rent-in practice; while (0) for non-participants. Renting farm land is a practice that help farm households to increase their agricultural crop production including barley production, which help to enhance the intensity of barley food availability. Therefore, farm households' participation in farm land rent-in practice and the intensity of their food availability from barley are hypothesized to associate positively and significantly. It is supported by the study of Hosaena and Stein (2012) that showed positive association between participation in land rent practice and food security in Ethiopia. Furthermore, Muraoka, *et. al.*, (2014) showed that land rent play a positive role in promoting household food security in rural Kenya.

Farm households' participation in support of rain-fed crop with Irrigation: it is a non-continuous and dichotomous explanatory variable expected to affect the intensity of barley food availability positively and significantly. Supporting rain fed crop with irrigation can increase agricultural crops yield, thereby, food availability from barley and other crops. Therefore, in this study, farm households' participation in support of rain-fed crop with irrigation and the intensity of food availability from barley are hypothesized positively and significantly. Use of irrigation (a proxy variable for rain fed crops support with irrigation) showed statistically significant and negative relationship with food insecurity in the study of Bogale and Shimelis (2009).

Annex 2. Multicollinearity tests results tabular presentation

Table 59 (Annex). Variable Inflation Factor (VIF) analysis output on barley technologies adoption (multivariate probit)

Variable	VIF	1/VIF
FARMLANDHHCULT	1.23	0.811081
LIVSTOCKSIZTLU	1.17	0.854240
MARKETDISTKM	1.07	0.937134
HHHFORMEDUYR	1.02	0.981389
HHSIZEADEQIV	1.02	0.983151
Mean VIF	1.10	

Source: Analyzed from own household survey data, 2014/2015

*No serious multicollinearity problem

Table 60 (Annex). Correlation Matrix analysis output for non-continuous explanatory variables used in farm households' barley technologies adoption (multivariate probit)

Discrete explanatory variables	HHHEAD SEX	FOODS ECSTAT US	INCOME STATUS	HHCRE DACCE SS	HHACE SAGRE XT	HHBA RSELL OPTIO NS	LAND RENTI NPART
HHHEADSEX	1.0000						
FOODSECSTATUS	0.0254	1.0000					
INCOMESTATUS	0.0110	0.4574	1.0000				
HHCREDACCESS	0.0092	0.0337	0.1260	1.0000			
HHACCESAGREXT	-0.0342	0.0380	-0.0061	0.0526	1.0000		
HHBARSELOPTNS	0.0092	0.1516	0.2055	0.0973	0.0787	1.0000	
LADRENTINPART	0.1545	0.0119	0.0749	0.0265	-0.0317	0.0289	1.0000

Source: Analyzed from own household survey data, 2014/2015

*No serious multicollinearity problem

Table 61 (Annex). Variable inflation factor analysis (VIF) result on continuous predictors in fertilizer adoption

Continuous Explanatory variables	Collinearity Statistics	
	Tolerance	VIF
Livestock size (TLU)	.340	2.940
Farm land size (Ha)	.792	1.263
Number of oxen HHs owned	.368	2.716
Credit center distance (Km)	.866	1.155
FTC distance (Km)	.095	10.490
DA office distance (Km)	.096	10.471
Market distance (Km)	.740	1.352
Distance from all-weather road (Km)	.882	1.134

Source: own computation from 2014/2015 household survey
*No serious multicollinearity problem

Table 62 (Annex). Correlation matrix result showed the multicollinearity result on non-continuous predictors used in fertilizer adoption analysis

Predictors	1=HH head marital status	2=HHs credit access	3= participation in Improved Livestock production	4=House hold head sex	5=Support rain fed crops with Irrigation	6=HHs' food availability status	7=HHs access to agricultural extension service	8=HHs' Participation in Belg Production	9=HHs' participation in barley selling options	10=HHs participation in Livestock Shared-in	11=HHs' Participation in Land Rent-in practices	12=HHs Participation in Irrigation production	13=Households' income status
1	1.000	-.004	-.009	.042	.031	-.022	-.047	-.032	.021	.085	-.024	-.028	-.011
2	-.004	1.000	-.006	-.007	-.015	.033	-.048	-.023	-.114	-.041	-.002	-.006	-.105
3	-.009	-.006	1.000	.012	.019	-.007	-.013	-.065	.096	-.130	-.227	-.018	-.078
4	.042	-.007	.012	1.000	-.005	-.024	.026	-.064	-.023	.054	-.157	.053	.006
5	.031	-.015	.019	-.005	1.000	-.035	.045	-.124	-.037	-.044	-.071	-.412	.028
6	-.022	.033	-.007	-.024	-.035	1.000	-.046	.010	-.046	.036	.024	.047	-.447
7	-.047	-.048	-.013	.026	.045	-.046	1.000	.027	-.057	-.051	.029	-.007	.042
8	-.032	-.023	-.065	-.064	-.124	.010	.027	1.000	-.018	-.049	-.028	.040	.054
9	.021	-.114	.096	-.023	-.037	-.046	-.057	-.018	1.000	.003	-.049	-.022	-.136
10	.085	-.041	-.130	.054	-.044	.036	-.051	-.049	.003	1.000	-.056	-.043	-.016
11	-.024	-.002	-.227	-.157	-.071	.024	.029	-.028	-.049	-.056	1.000	-.077	-.040
12	-.028	-.006	-.018	.053	-.412	.047	-.007	.040	-.022	-.043	-.077	1.000	-.094
13	-.011	-.105	-.078	.006	.028	-.447	.042	.054	-.136	-.016	-.040	-.094	1.000

Source: own computation from 2014/2015 household survey

*No serious multicollinearity problem

Table 63 (Annex). correlation matrix output conducted to test multicollinearity problem on non-continuous predictors used in households' aggregate income status analysis based on (3781 Eth. Birr) (Logit)

Predictors	1=HHACESBARLEXT	2=HHADOPIMPBARSEED	3=HHHEADSEX	4=HHADOPFREQPLOW	5=HHOFARMPART	6=HHPARTIMPLIVPROD	7=BARSELOPTNS	8=HHFORMCREDACES	9=HHADOPFERTBARL	10=HHADOPCOMPBARL	11=HHADOPWEEDCIDE	12=HHADOPFRMDRNAGE	13=HHADOPFRQWEDING
1	1.000	.015	-.062	-.024	.001	-.026	-.002	-.055	-.069	-.029	-.019	-.083	.060
2	.015	1.000	.034	.138	-.093	-.093	-.081	-.148	-.108	-.200	-.080	.132	-.192
3	-.062	.034	1.000	-.024	-.013	-.015	-.017	.020	.005	-.004	-.046	-.023	-.013
4	-.024	.138	-.024	1.000	.034	-.138	.040	-.068	-.209	-.162	-.169	-.259	-.390
5	.001	-.093	-.013	.034	1.000	-.069	-.009	-.142	-.011	-.078	-.030	-.023	.062
6	-.026	-.093	-.015	-.138	-.069	1.000	-.071	-.126	-.075	-.098	.089	-.041	.152
7	-.002	-.081	-.017	.040	-.009	-.071	1.000	-.044	-.114	-.062	-.058	-.155	-.161
8	-.055	-.148	.020	-.068	-.142	-.126	-.044	1.000	.026	.022	-.060	.108	-.039
9	-.069	-.108	.005	-.209	-.011	-.075	-.114	.026	1.000	-.051	-.108	-.083	.137
10	-.029	-.200	-.004	-.162	-.078	-.098	-.062	.022	-.051	1.000	.061	.107	-.088
11	-.019	-.080	-.046	-.169	-.030	.089	-.058	-.060	-.108	.061	1.000	-.075	-.145
12	-.083	.132	-.023	-.259	-.023	-.041	-.155	.108	-.083	.107	-.075	1.000	-.003
13	.060	-.192	-.013	-.390	.062	.152	-.161	-.039	.137	-.088	-.145	-.003	1.000

Source: own computation from 2014/2015 HH survey data

*No serious multicollinearity problem

Table 64 (Annex). Variable Inflation Factor (VIF) analysis output on continuous predictors used in sample HHs' aggregate income status analysis based on (3781 Eth. Birr) (Logit)

Predictors	Collinearity Statistics	
	Tolerance	VIF
Household head age (years)	.844	1.185
Household head formal education (years of schooling)	.884	1.131
Household Size (Adult Equivalent)	.825	1.212
Households' Livestock Ownership (TLU)	.701	1.426
Farm Land size (Ha)	.783	1.278
Market distance(Kms)	.900	1.111
Available food (Kcal)	.775	1.291

Source: own computation from 2014/2015 HH survey data

*No serious multicollinearity problems

Table 65 (Annex). Multicollinearity test result of VIF on farm HHs' aggregate income intensity in (Eth. Birr)

Continuous variables	Multicollinearity test result before market distance removing		Multicollinearity test result aftermarket distance removing	
	Tolerance	VIF	Tolerance	VIF
AGEYRLOG	.821	1.217	.823	1.215
HHHFORMEDUYRS	.870	1.149	.877	1.140
HHSIZEADEQV	.806	1.241	.806	1.241
LIVSTOKOWNTLU	.682	1.466	.683	1.464
FARMLADHHCULT	.770	1.299	.793	1.261
HHFOODAVLOG	.712	1.405	.730	1.371
MARKDISTKM	.909	1.100		

Source: own analysis output

*No serious multicollinearity problem

Table 66 (Annex). Multicollinearity test using correlation matrix among non-continuous predictors expected to affect farm households' aggregate income intensity (Eth. Birr)

No.	1=LANDRENTEDINPART	2=HHADOPFRQWEDING	3=HHACESBARLEXT	4=HHOFFARMPART	5=HHADOPFERTBARL	6=HHHEADSEX	7=HHFORMCREDACES	8=HHADOPCOMPBARL	9=HHADOPFRMDRNAGE	10=BARSELOPTNS	11=HHPARTIMPLIVPROD	12=HHADOPWEEDCIDE	13=HHADOPIMPBARSEED	14=HHADOPFREQPLOW
1	1.000	.046	-.012	-.090	-.043	-.146	-.060	.022	-.059	.047	-.205	-.068	-.002	-.047
2	.046	1.000	.060	.057	.135	-.019	-.042	-.087	-.006	-.158	.139	-.148	-.192	-.392
3	-.012	.060	1.000	.002	-.068	-.060	-.054	-.030	-.082	-.003	-.023	-.018	.015	-.023
4	-.090	.057	.002	1.000	-.007	.001	-.136	-.079	-.017	-.014	-.049	-.024	-.092	.038
5	-.043	.135	-.068	-.007	1.000	.011	.029	-.052	-.080	-.116	-.065	-.105	-.108	-.206
6	-.146	-.019	-.060	.001	.011	1.000	.029	-.007	-.014	-.024	.015	-.035	.034	-.017
7	-.060	-.042	-.054	-.136	.029	.029	1.000	.021	.111	-.047	-.111	-.056	-.148	-.065
8	.022	-.087	-.030	-.079	-.052	-.007	.021	1.000	.106	-.060	-.101	.059	-.200	-.163
9	-.059	-.006	-.082	-.017	-.080	-.014	.111	.106	1.000	-.158	-.028	-.071	.132	-.256
10	.047	-.158	-.003	-.014	-.116	-.024	-.047	-.060	-.158	1.000	-.079	-.061	-.081	.038
11	-.205	.139	-.023	-.049	-.065	.015	-.111	-.101	-.028	-.079	1.000	.101	-.091	-.125
12	-.068	-.148	-.018	-.024	-.105	-.035	-.056	.059	-.071	-.061	.101	1.000	-.079	-.165
13	-.002	-.192	.015	-.092	-.108	.034	-.148	-.200	.132	-.081	-.091	-.079	1.000	.137
14	-.047	-.392	-.023	.038	-.206	-.017	-.065	-.163	-.256	.038	-.125	-.165	.137	1.000

Source: own organization

*No serious multicollinearity problem

Table 67 (Annex). Multicollinearity test analysis output using correlation matrix analysis on non-continuous predictors expected to affect farm households' intensity of income from barley (Eth. Birr)

Non-Continuous predictors	1=HHPARTIN BARVAD	2=HHHEADSE X	3=ACESBARL EXT	4=OFFARMPA RT	5=PARTIRRGP ROD	6=ADOPFREQ PLOW	7=ADOPIMPB ARSEED	8=LANDRENT INPART	9=PARBELGP ROD	10=FORMCRE DACES	11=ADOPWEE DCIDE	12=ADOPCOM PBARL	13=ADOPFER TBARL	14=ADOPFRM DRNAGE	15=ADOPFRQ WEDING
1	1.000	.003	.022	-.030	-.056	.080	-.118	.037	-.230	-.084	-.052	-.069	-.078	-.189	-.149
2	.003	1.000	-.056	.009	.064	-.011	.039	-.149	-.062	.030	-.030	.000	-.011	-.019	-.025
3	.022	-.056	1.000	.007	-.051	-.026	.013	-.007	-.098	-.045	-.006	-.019	-.085	-.077	.052
4	-.030	.009	.007	1.000	.035	.031	-.088	-.103	-.079	-.132	-.007	-.072	-.032	-.013	.063
5	-.056	.064	-.051	.035	1.000	.042	.050	-.120	-.011	-.068	.018	-.018	-.107	-.070	.057
6	.080	-.011	-.026	.031	.042	1.000	.122	-.077	-.023	-.087	-.154	-.180	-.219	-.272	-.384
7	-.118	.039	.013	-.088	.050	.122	1.000	-.026	-.027	-.149	-.061	-.199	-.129	.136	-.177
8	.037	-.149	-.007	-.103	-.120	-.077	-.026	1.000	-.038	-.073	-.046	.008	-.048	-.056	.068
9	-.230	-.062	-.098	-.079	-.011	-.023	-.027	-.038	1.000	-.077	-.108	-.113	.221	-.009	.082
10	-.084	.030	-.045	-.132	-.068	-.087	-.149	-.073	-.077	1.000	-.032	.027	.008	.125	-.031
11	-.052	-.030	-.006	-.007	.018	-.154	-.061	-.046	-.108	-.032	1.000	.085	-.125	-.060	-.168
12	-.069	.000	-.019	-.072	-.018	-.180	-.199	.008	-.113	.027	.085	1.000	-.085	.113	-.081
13	-.078	-.011	-.085	-.032	-.107	-.219	-.129	-.048	.221	.008	-.125	-.085	1.000	-.086	.141
14	-.189	-.019	-.077	-.013	-.070	-.272	.136	-.056	-.009	.125	-.060	.113	-.086	1.000	-.004
15	-.149	-.025	.052	.063	.057	-.384	-.177	.068	.082	-.031	-.168	-.081	.141	-.004	1.000

Source: own computation from 2014/2015 HH survey data

*No serious multicollinearity problem

Table 68 (Annex). Multicollinearity test analysis output using Variable Inflation Factor (VIF) method on continuous predictors affecting farm households'intensity of barley income (Eth. Birr)

Continuous Predictors	Collinearity Statistics	
	Tolerance	VIF
Household head age (years)	.844	1.185
Household head formal education (years of schooling)	.884	1.131
Household Size (Adult Equivalent)	.825	1.212
Households' Livestock Ownership (TLU)	.701	1.426
Farm Land size (Ha)	.783	1.278
Market distance(Km)	.900	1.111
Available food (Kcal)	.775	1.291

Source: own computation from 2014/2015 HH survey data

*No serious multicollinearity problem

Table 69 (Annex). Multicollinearity test output among the continuous predictors affecting the farm households'aggregate food availability status (Kcal) using Variable Inflation factor (VIF)

Predictors	Collinearity Statistics	
	Tolerance	VIF
HH head age (year)	.847	1.181
HH head formal education (years of schooling)	.882	1.133
Farm land size (Ha)	.795	1.259
HH size (Adult Equivalent)	.827	1.209
HHs' livestock size(TLU)	.646	1.547
HHs' Annual income (Eth. Birr)	.700	1.429

Source: own computation from 2014/2015 HHs' survey

*Among continuous predictors, market distance (Km) showed multicollinearity problem. Hence, it was discarded and was not included in logit regression model for further analysis.

Table 70 (Annex). Correlation matrix result to check multicollinearity problem among non-continuous predictors used in households' aggregate food availability status (Kcal)

Predictors	**ACCESSAGREXT**	**ADOPIMPBASEED**	**HHHEADSEX**	**ADOPFRQPLOW**	**FORMCREDACES**	**ADOFERBAR**	**ADOPCOMPBARL**	**ADOWEDCIDE**	**ADOPFRMDRNAG**	**ADOPFRQWEDIG**
ACCESSAGREXT	1.000	.002	-.082	-.035	-.022	-.093	-.062	-.048	-.085	.005
ADOIMPBARSED	.002	1.000	.031	.133	-.186	-.130	-.228	-.080	.115	-.193
HHHEADSEX	-.082	.031	1.000	-.024	.013	.004	-.005	-.043	-.026	-.009
ADOPFREQPLOW	-.035	.133	-.024	1.000	-.083	-.218	-.174	-.155	-.265	-.379
FORMCREDACES	-.022	-.186	.013	-.083	1.000	.006	-.008	-.057	.090	-.014
ADOPFERTBARL	-.093	-.130	.004	-.218	.006	1.000	-.066	-.106	-.106	.141
ADOPCOMPBARL	-.062	-.228	-.005	-.174	-.008	-.066	1.000	.067	.094	-.079
ADOPWEEDCIDE	-.048	-.080	-.043	-.155	-.057	-.106	.067	1.000	-.079	-.169
ADOPFRMDRNAGE	-.085	.115	-.026	-.265	.090	-.106	.094	-.079	1.000	-.014
ADOPFRQWEDING	.005	-.193	-.009	-.379	-.014	.141	-.079	-.169	-.014	1.000

Source: own computation from 2014/2015 HHs' survey

*No serious multicollinearity problem

Table 71 (Annex). Multicollinearity test output among non-continuous predictors affecting the farm HHs' intensity of aggregate food availability (Kcal) using correlation matrix analysis method;

Predictors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1=PARTINBARVAD	1.000	.027	.025	.096	-.094	.000	-.052	-.206	-.036	-.085	.045	-.121	-.036	-.772
2=HHHEADSEX	.027	1.000	-.062	-.012	.035	-.143	.002	-.061	-.030	.035	.002	-.014	-.028	-.030
3=ACESBARLEXT	.025	-.062	1.000	-.024	-.056	-.014	-.023	-.107	-.012	.028	-.103	-.083	.056	-.014
4=ADOPFREQPLOW	.096	-.012	-.024	1.000	-.083	-.071	-.178	-.024	-.155	.122	-.206	-.269	-.385	-.056
5=FORMCREDACES	-.094	.035	-.056	-.083	1.000	-.095	.017	-.084	-.031	-.160	-.007	.121	-.023	.045
6=LANDRENTINPART	.000	-.143	-.014	-.071	-.095	1.000	-.001	-.046	-.045	-.029	-.067	-.066	.080	.023
7=ADOPCOMPBARL	-.052	.002	-.023	-.178	.017	-.001	1.000	-.118	.085	-.206	-.089	.112	-.077	.007
8=PARBELGPROD	-.206	-.061	-.107	-.024	-.084	-.046	-.118	1.000	-.107	-.034	.210	-.010	.081	.074
9=ADOPWEEDCIDE	-.036	-.030	-.012	-.155	-.031	-.045	.085	-.107	1.000	-.063	-.122	-.058	-.169	.004
10=ADOPIMPBARSED	-.085	.035	.028	.122	-.160	-.029	-.206	-.034	-.063	1.000	-.129	.138	-.176	.013
11=ADOPFERTBARL	.045	.002	-.103	-.206	-.007	-.067	-.089	.210	-.122	-.129	1.000	-.092	.156	-.129
12=ADOPFRMDRNAG	-.121	-.014	-.083	-.269	.121	-.066	.112	-.010	-.058	.138	-.092	1.000	.001	-.004
13=ADOPFRQWEDIG	-.036	-.028	.056	-.385	-.023	.080	-.077	.081	-.169	-.176	.156	.001	1.000	-.072
14=BARSELOPTNS	-.772	-.030	-.014	-.056	.045	.023	.007	.074	.004	.013	-.129	-.004	-.072	1.000

Source: own computation from 2014/2015 HHs survey data

*No serious multicollinearity problem

Table 72 (Annex). Multicollinearity test output of Variable Inflation factor (VIF) among the continuous predictors affecting farmers' aggregate intensity of food availability (Kcal)

Predictors	Collinearity Statistics	
	Tolerance	VIF
HH age (Log yr)	.819	1.221
HH education (Log yr)	.880	1.136
Livestock size (Log TLU)	.108	9.282
Farm land size (Ha)	.858	1.165
HH size (Adult Equivalent)	.108	9.220
HH Income (Eth. Birr Log)	.808	1.238

Source: own computation from 2014/2015 HHs survey data

*As shown in the variable inflation factor analysis output in Table 51, market distance (Km) showed multicollinearity problem. As a result, it was discarded and was not included in the multiple linear regression model for further analysis;

Table 73 (Annex). Variable Inflation factor (VIF) output on multicollinearity test among continuous predictors proposed to affect the intensity of barley food availability (Kcal)

Predictors	Collinearity Statistics	
	Tolerance	VIF
HH head age in year	.847	1.181
HH head formal education (yrs of schooling)	.882	1.134
Farm land size (Ha)	.794	1.259
Livestock size (TLU)	.644	1.553
HH size (Adult Equivalent)	.827	1.209
HH's Annual Income (Eth. Birr)	.695	1.440

Source: own computation from 2014/2015 HHs survey data

*No serious multicollinearity problem

Table 74 (Annex). Multicollinearity test analysis result using correlation matrix among non-continuous predictors used in the analysis of intensity of barley food availability (Kcal)

Predictors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1=LANDRENINPART	1.000	.075	-.011	-.036	-.113	-.144	-.064	-.089	-.009	-.069	.048	-.047	-.022	-.067
2=ADOFRQWEDING	.075	1.000	.055	.072	.038	-.026	-.004	-.028	-.076	.159	-.160	-.170	-.181	-.384
3=ACESBARLEXT	-.011	.055	1.000	-.101	-.029	-.063	-.080	-.052	-.024	-.104	.012	-.012	.032	-.026
4=PARBELGPROD	-.036	.072	-.101	1.000	-.093	-.059	-.035	-.101	-.137	.221	-.124	-.118	-.047	-.001
5=RAIFEDCROPSUP	-.113	.038	-.029	-.093	1.000	.019	-.016	-.051	.070	.021	-.111	.021	-.067	-.035
6=HHHEADSEX	-.144	-.026	-.063	-.059	.019	1.000	-.011	.037	.004	.001	-.017	-.029	.036	-.015
7=ADOPFRMDRAGE	-.064	-.004	-.080	-.035	-.016	-.011	1.000	.112	.105	-.088	-.151	-.063	.130	-.260
8=FORMCREDACES	-.089	-.028	-.052	-.101	-.051	.037	.112	1.000	.009	-.004	-.038	-.036	-.166	-.073
9=ADOPCOMPBARL	-.009	-.076	-.024	-.137	.070	.004	.105	.009	1.000	-.085	-.059	.085	-.215	-.176
10=ADOPFERTBARL	-.069	.159	-.104	.221	.021	.001	-.088	-.004	-.085	1.000	-.149	-.120	-.127	-.212
11=BARSELOPTNS	.048	-.160	.012	-.124	-.111	-.017	-.151	-.038	-.059	-.149	1.000	-.039	-.075	.033
12=ADOPWEDCIDE	-.047	-.170	-.012	-.118	.021	-.029	-.063	-.036	.085	-.120	-.039	1.000	-.068	-.153
13=ADOIMPBARSED	-.022	-.181	.032	-.047	-.067	.036	.130	-.166	-.215	-.127	-.075	-.068	1.000	.133
14=ADOPFREQPLOW	-.067	-.384	-.026	-.001	-.035	-.015	-.260	-.073	-.176	-.212	.033	-.153	.133	1.000

Source: own computation from 2014/2015 HHs survey data

*No serious multicollinearity problem

Table 75 (Annex). Multicollinearity test result of continuous predictors using VIF in ordered Legit regression model analysis in farm households' perception level

Predictors	Collinearity Statistics	
	Tolerance	VIF
FARMLANDSZHA	.852	1.174
LOGAGEHHHEAD	.891	1.122
LOGHHHEDUCYR	.890	1.124
LOGLIVSTOCKTLU	.799	1.251
LOGCREDITDISTKM	.827	1.210
LOGINCOMEBIRR	.812	1.232
LOGMARKDISTKM	.784	1.275
LOGDAOFFICEKMs	.714	1.400

Source: own computation from 2014/2015 HHs' survey data

*No serious multicollinearity problem

Table 76 (Annex). Multicollinearity test result among non-continuous predictors using correlation matrix analysis in ordered Logit regression analysis in farm households' perception level

Predictors	MONTHEXCONTFRQ	HHINCOMESTATUS	HHHEADSEX	FTCAVALABLTY	PARTIMPLIVSPROD	NUMBARTECHADOP	FOODAVLSTATUS
MONTHEXCONTFRQ	1.000	.040	.100	.059	-.073	-.169	.044
HHINCOMESTATUS	.040	1.000	.016	-.081	-.087	-.148	-.438
HHHEADSEX	.100	.016	1.000	-.010	-.027	-.072	-.015
FTCAVALABLTY	.059	-.081	-.010	1.000	-.057	.000	.028
PARTIMPLIVSPROD	-.073	-.087	-.027	-.057	1.000	.046	.003
NUMBARTECHADOP	-.169	-.148	-.072	.000	.046	1.000	-.081
FOODAVLSTATUS	.044	-.438	-.015	.028	.003	-.081	1.000

Source: own computation from 2014/2015 HHs' survey data

*No serious multicollinearity problem

Table 77 (Annex). Continuous predictors multicollinearity test result on households' intensity of perception towards extension service (Ordered Logit)

Predictors	Collinearity Statistics	
	Tolerance	VIF
LOGAGEHHHEAD	.891	1.122
LOGHHHEDUCYR	.890	1.124
LOGLIVSTOCKTLU	.799	1.251
FARMLANDCULHA	.852	1.174
LOGCREDISTKM	.827	1.210
LOGINCOMEBIRR	.812	1.232
LOGMARKDISTKM	.784	1.275
LOGDAOFFDISTKM	.714	1.400

Source: Own computation from 2014/2015 HHs' survey

*In the VIF test result, among the continuous predictors, household size in adult equivalent showed multicollinearity problem. As a result, it was discarded not to be included in the Censored Tobit regression model and not to be used in further regression analysis.

Table 78 (Annex). Non-continuous predictors multicollinearity test result on households' intensity of mean perception towards extension service

Predictors	PARBAR VADNS	HHHEA DSEX	PARIMPLI VPROD	ACCESA GREXT	HHOFFA RMPART
PARBARVADNS	1.000	-.030	.026	-.081	.033
HHHEADSEX	-.030	1.000	-.020	.037	-.007
PARIMPLIVPROD	.026	-.020	1.000	-.009	-.122
ACCESAGREXT	-.081	.037	-.009	1.000	.005
HHOFFARMPART	.033	-.007	-.122	.005	1.000

Source: Own computation from 2014/2015 HHs' survey

*No serious multicollinearity problem

Annex 3. The hypothesized coef. signs and the result (observed) coef. signs of independent variables used in econometrics regression models analyses conducted to determine the effects of predictors on different dependent variables

Table 79 (Annex). List of independent variables used in barley technologies adoption

Explanatory variables hypothesized to affect barley technologies adoption	Continuous/ Non-continuous	The coefficients expected/hypothesized signs and the results signs														Number of dependent variable affected by each predictor
		Fertilizer		Compost		Weedicide		Frequent plow		Frequent weeding		Improved barley seed		Farm land Drainage		
		Expected sign	Result sign	Expected sign	Result sign	Expected sign	Result sign	Expected sign	Result sign	Expected sign	Result sign	Expected sign	Result sign	Expected sign	Result sign	
Household head age in (yrs)	Continuous	-	+	-	-	-	-	-	-	-	-	-	-	-	+	1
Household's Livestock size (TLU)	Continuous	+	+	+	-	+	+	+	+	+	+	+	-	+	+	2
Household's farm land size (Ha)	Continuous	+	+	+	+	+	-	+	-		-	+	+	+	+	4
Household size in Adult Equivalent	Continuous	-	+	-	+	-	+	-	+	-	+	-	-	-	+	2
HHs home distance from market (Km)	Continuous	-	+	-	-	-	-	-	-	-	+	-	+	-	-	1
HH head formal education in (yrs)	Continuous	+	-	+	+	+	-	+	+	+	+	+	+	+	+	0
Household head sex (male)	Non-continuous	+	+	+	+	+	+	+	-	+	-	+	+	+	+	1
Household's income status	Non-continuous	+	+	+	+	+	+	+	+	+	+	+	-	+	+	3
Household's credit access	Non-continuous	+	+	+	+	+	+	+	+	+	+	+	+	+	-	5
HH's access to extension service	Non-continuous	+	+	+	+	+	+	+	+	+	+	+	+	+	+	6
Household's food availability status	Non-continuous	+	+	+	+	+	-	+	+	+	+	+	+	+	+	1
HH's participation in barley output markets	Non-continuous	+	+	+	+	+	+	+	+	+	+	+	+	+	+	7
HH's participation in land rent-in practice	Non-continuous	+	+	+	+	+	+	+	+	+	-	+	-	+	-	0

Source: own organization

Table 80 (Annex). List of independent variables used in fertilizer adoption (Kg)

Independent variables hypothesized to affect farm HHs' adoption of chemical fertilizer	Continuous/non-continuous	Expected Coef. sign	Result Coef. sign
Livestock Size (TLU)	Continuous	+	-
Farm land size (Ha)	Continuous	+	+
Market distance (Km)	Continuous	-	+
HHs' home distance from FTC in Km	Continuous	-	+
HHs' home distance from DA office in Km	Continuous	-	-
Credit center distance Km	Continuous	-	-
All weather distance Km	Continuous	-	+
HHs' oxen ownership in number	Continuous	+	+
Household sex	Non-Continuous	+	-
HHs' marital status	Non-Continuo	+	+
Household food avail. Status	Non-Continuous	+	+
Household income status	Non-Continuous	+	+
Farm households credit access	Non-Continuous	+	+
Farm HHs' access to Extension service	Non-Continuous	+	+
Farm HHs' participation in barley selling options	Non-Continuous	+	+
HHs' participation in land-rent-in practice	Non-Continuous	+	-
HHs' participation in livestock shared-in	Non-Continuous	+	+
HHs' participation in *Belg* crop production	Non-Continuous	+	-
HHs' participation in irrigation production	Non-Continuous	+	+
HHs' participation in rain fed crops support with irrigation	Non-Continuous	+	+
HHs' participation in improved livestock production	Non-Continuous	+	+

Source: own organization

Table 81(Annex). List of independent variables used in farm households' perception level analysis

Independent variables affecting the dependent variables	Continuous/Non-continuous	Expected coef. sign	Result coef. sign
Household's head age in years	Continuous	-	+
HH head formal education in (yrs) of schooling	Continuous	+	+
Household's Livestock size Log(TLU)	Continuous	+	-
Household's farm land size (Ha)	Continuous	+	+
Credit center distance (Km)	Continuous	-	-
Market distance (Km)	Continuous	-	+
Household's head sex	Non-continuous	+	-
Households' food availability status	Non-continuous	+	-
HH's participation in improved Livestock Production	Non-continuous	+	+
Households' income status	Non-continuous	+	+
Farmers' training center availability	Non-continuous	+	+
Barley technologies adoption in number	Non-continuous	+	+
Frequency of extension contacts	Non-continuous	+	+

Source: Own organization

Table 82 (Annex). List of independent variables used in farm households' intensity of perception analysis

Independent variables used to analyze farm households' intensity of perception towards extension service	Continuous/ non-continuous	Expected coef. sign	Result coef. sign
Household age (years)	Continuous	-	+
HHs head formal education (years of schooling)	Continuous	+	+
Household's Livestock size (TLU)	Continuous	+	-
Household's farm land size (Ha)	Continuous	+	+
Credit center distance (Km)	Continuous	-	-
Market distance (Km)	Continuous	-	+
Household's income in Eth. Birr	Continuous	+	+
DA office distance (Km)	Continuous	-	-
Household's head sex	Non-continuous	+	-
Households access to agricultural extension service	Non-continuous	+	+
HH's participation in improved livestock production	Non-continuous	+	+
Household's off-farm participation	Non-continuous	+	+
HH's participation in barley value addition practices	Non-continuous	+	-

Source: Own organization

Table 83(Annex). List of independent variables in farmer' barley income (Eth. Birr) analysis

Independent variables used in the analysis of farm households' income from barley	Continuous/Non-continuous	Expected coef sign	Result coef. sign
Household head age	Continuous	-	+
Household head formal education in years of schooling	Continuous	+	+
Household's size in Adult Equivalent	Continuous	-	-
Household's Livestock size in (TLU)	Continuous	+	+
Household's farm land size (Ha):	Continuous	+	+
Household's home distance from market (Km)	Continuous	-	-
Household aggregate food availability(Kcal)	Continuous	+	+
Household's head sex	Non-continuous	+	-
Households' fertilizer adoption	Non-continuous	+	+
Household's adoption of compost	Non-continuous	+	+
Household's weedicide adoption	Non-continuous	+	-
Household's adoption of frequent plow	Non-continuous	+	-
Household's adoption of frequent weeding	Non-continuous	+	-
Household's adoption of improved seed	Non-continuous	+	-
Household's adoption of farm drainage	Non-continuous	+	-
Household's access to formal credit	Non-continuous	+	-
Farm household's off-farm participation	Non-continuous	+	+
Household's access to barley extension service	Non-continuous	+	-
Farm household's participation in Land Rent-in practice	Non-continuous	+	+
Farm HH's participation in barley value additions	Non-continuous	+	+
Farm HH's income participation in irrigation production	Non-continuous	+	+
Farm households' participation in *Belg* production	Non-continuous	+	+

Source: Own organization

Table 84 (Annex). List of predictors in households' aggregate income intensity (Eth. Birr) analysis

Independent variables used to analyze farm HHs' aggregate income intensity (Eth. Birr)	Continuous/non-continuous	Expected coef. sign	Expected coef. sign
Household head age Log (years)	Continuous	-	-
Household head formal education in years of schooling	Continuous	+	+
Household's size in Adult Equivalent	Continuous	-	-
Household's Livestock size in (TLU)	Continuous	+	+
Household's farm land size (Ha)	Continuous	+	+
Household's food availability Log (Kcal)	Continuous	+	+
Household's head sex	Non-continuous	+	-
Households' fertilizer adoption	Non-continuous	+	-
Household's adoption of compost	Non-continuous	+	+
Household's weedicide adoption	Non-continuous	+	+
Household's adoption of frequent plow	Non-continuous	+	+
Household's adoption of frequent weeding	Non-continuous	+	-
Household's adoption of improved seed	Non-continuous	+	-
Household's adoption of farm drainage	Non-continuous	+	-
Household's access to formal credit	Non-continuous	+	+
Household's off-farm participation	Non-continuous	+	+
HH's participation in barley output market options	Non-continuous	+	+
Household's access to barley extension service	Non-continuous	+	-
HH's participation in improved livestock production	Non-continuous	+	+
Farm HH's participation in Land Rent-in practice	Non-continuous	+	+

Source: own organization

Table 85(Annex). List of predictors used in households' aggregate income status analysis

Independent variables HHs' income status	Continuous/non-continuous	Expected coef. sign	Expected coef. sign
Household head age	Continuous	-	-
Household head formal education in years of schooling	Continuous	+	+
Household's size in Adult Equivalent	Continuous	-	-
Household's Livestock size in (TLU)	Continuous	+	+
Household's farm land size (Ha)	Continuous	+	+
Household's home distance from market (Km)	Continuous	-	-
Household aggregate food availability (Kcal)	Continuous	+	+
Household's head sex	Non-continuous	+	-
Households' fertilizer adoption	Non-continuous	+	+
Household's adoption of compost	Non-continuous	+	+
Household's weedicide adoption	Non-continuous	+	+
Household's adoption of frequent plow	Non-continuous	+	+
Household's adoption of frequent weeding	Non-continuous	+	-
Household's adoption of improved seed	Non-continuous	+	-
Household's adoption of farm drainage	Non-continuous	+	+
Household's access to formal credit	Non-continuous	+	+
Household's off-farm participation	Non-continuous	+	+
Household's access to agricultural extension service	Non-continuous	+	-
HH's participation in improved livestock production	Non-continuous	+	+
HH's participation in barley output market options	Non-continuous	+	+

Source: own organization

Table 86 (Annex). Farm households' intensity of barley food availability determinants

Independent variables affecting the intensity of barley food availability at HH level	Continuous/Non-continuous	Expected Coef. Sign	Expected Coef. Sign
Household head age (years)	Continuous	-	-
HH head formal education (years of schooling)	Continuous	+	-
Farm Land size (Ha)	Continuous	+	+
Household size (Adult equivalent)	Continuous	+	+
Household Livestock size (TLU)	Continuous	+	+
Annual Income (Eth. Birr)	Continuous	+	+
Household head sex	Non-continuous	+	-
Households' fertilizer adoption	Non-continuous	+	+
Household's adoption of compost	Non-continuous	+	+
Farm household's weedicide adoption	Non-continuous	+	-
Household's adoption of frequent plow	Non-continuous	+	-
Farm household's adoption of frequent weeding	Non-continuous	+	+
Household's adoption of improved seed	Non-continuous	+	-
Household's adoption of farm drainage	Non-continuous	+	-
Farm house holds formal credit access	Non-continuous	+	-
Farm households' access to barley extension service	Non-continuous	+	+
Household participation in barley selling options	Non-continuous	+	+
Households participation in *Belg* production	Non-continuous	+	+
Farm HH's participation in Land Rent-in practice	Non-continuous	+	+
HHs' participation in rain-fed crop irrigation support	Non-continuous	+	+

Source: own organization

Table 87 (Annex). Predictors in farm households aggregate food availability (Kcal)

Independent variables affecting aggregate intensity of farm households' food availability (Kcal)	Continuous/Non-continuous	Expected coef.sign	Expected Coef. Sign
Household head age log (years)	Continuous	-	-
HH's head formal education log (years of schooling)	Continuous	+	-
Household size (Adult. equiv.)	Continuous	-	-
Households' livestock ownership (TLU)	Continuous	+	+
Farm land size (Ha)	Continuous	+	+
Household income log (Eth. Birr)	Continuous	+	+
Household head sex	Non-continuous	+	+
Households' fertilizer adoption	Non-continuous	+	-
Household's weedicide adoption	Non-continuous	+	+
Farm household's adoption of compost	Non-continuous	+	+
Household's adoption of frequent plow	Non-continuous	+	-
Household's adoption of frequent weeding	Non-continuous	+	+
Household's adoption of farm drainage	Non-continuous	+	+
Household's adoption of improved seed	Non-continuous	+	-
Household's access to formal credit	Non-continuous	+	-
HH's access to agricultural extension service	Non-continuous	+	+
Household's participation *Belg* production	Non-continuous	+	+
Household's Land-rent-in participation	Non-continuous	+	+
HH's participation in barley selling options	Non-continuous	+	+
HH's participation in barley value addition practices	Non-continuous	+	-

Source: own organization

Table 88 (Annex). Predictors used in aggregate food availability status of farm households

Explanatory Variables	Continuous/ non-continuous	Expected Coef. sign	Expected Coef. Sign
Household head age	Continuous	-	+
HH head formal education (years of schooling)	Continuous	+	+
Household size (Adult Equivalent)	Continuous	-	-
Household's Livestock size (TLU)	Continuous	+	+
Household's farm land size (Ha)	Continuous	+	+
Household's income in Eth. Birr	Continuous	+	+
Household's head sex	Non-continuous	+	+
Households' fertilizer adoption	Non-continuous	+	-
Household's adoption of compost	Non-continuous	+	+
Household's weedicide adoption	Non-continuous	+	+
Household's adoption of frequent plow	Non-continuous	+	-
Household's adoption of frequent weeding	Non-continuous	+	+
Household's adoption of improved seed	Non-continuous	+	-
Household's adoption of farm drainage	Non-continuous	+	+
Household's access to formal credit	Non-continuous	+	-
HH's access to agricultural extension service	Non-continuous	+	+

Source: own organization

Annex 4. Summary independent variables with their observed coef signs from Annex Table 80-Annex Table 88)

Table 89 (Annex). Summary of Independent variables regarding the observed coef. signs from (Annex table 80-88);

No.	Independent variables hypothesized to affect dependent variables	The observed/result sign of coef.,after analyses											
		1	2	3	4	5	6	7	8	9	+	-	Sum
1	Household head age (-)	+	-	-	-	-	-	+	+	+	4	5	9
2	HH head formal edu. in years of schooling (+)	+		+	+	-	-	+	+	+	6	2	8
3	Household's size in Adult Equivalent (-)	-		-	-	+	-	-			1	5	6
4	Household's Livestock size in/TLU (+)	+	-	+	+	+	+	+	-	-	6	3	9
5	Household's farm land size/Ha (+)	+	+	+	+	+	+	+	+	+	9	-	9
6	HH's home distance from market/Km (-)	-	+		-				+	+	3	2	5
7	HHs' home distance from FTC in Km (-)	+									1	-	1
8	HHs' home distance from DA office Km (-)	-								-	-	2	2
9	Credit center distance Km (-)	-							-	-	-	3	3
10	All-weather road distance Km (-)	+									1	-	1
11	HH's aggregate food availability/Kcal (+)	+		+	+						3	-	3
12	Household's income /Eth. Birr (+)					+	+	+		+	4	-	4
13	HHs' oxen ownership in number (+)	+									1	-	1
14	Household's head sex (+)	-	-	-	-	-	+	+	-	-	2	7	9
15	HHs' marital status (+)	+									1	-	1
16	Household food avail. Status (+)	+							-		1	1	2

17	Household income status (+)	+							+		2	-	2
18	Households' fertilizer adoption (+)	+		-	+	+	-	-			3	3	6
19	Household's adoption of compost (+)	+		+	+	+	+	+			6	-	6
20	Household's weedicide adoption (+)	-		+	+	-	+	+			4	2	6
21	Household's adoption of frequent plow (+)	-		+	+	-	-	-			2	4	6
22	Household's adoption of frequent weeding (+)	-		-	-	+	+	+			3	3	6
23	Household's adoption of improved seed (+)	-		-	-	-	-	-			-	6	6
24	Household's adoption of farm drainage (+)	-		-	+	-	+	+			3	3	6
25	Household's access to formal credit (+)	-	+	+	+	-	-	-			3	4	7
26	Farm household's off-farm participation (+)	+		+	+					+	4	-	4
27	Farmers' training center availability/FTC (+)								+		1	-	1
28	Barley technologies adoption in number (+)								+		1	-	1
29	Frequency of extension contacts (+)								+		1	-	1
30	HH's access to barley extension service (+)	-	+	-	-	+	+	+		+	5	3	8
31	Farm HHs' partic. in barley selling options (+)	+		+	+	+	+				5	-	5
32	Farm HHs' particip. in Land Rent-in practice (+)	+	-			+	+				3	1	4
33	HHs' participation in livestock shared-in (+)	+		+							2	-	2
34	HHs' particip. in improved livestock prod^{n} (+)	+		+	+				+	+	5	-	5
35	Farm HH's partic. in barley value additions (+)	+					-			-	1	2	3
36	Farm HHs' participation in irrigation produ^{n} (+)	+	+								2	-	2
37	HHs' particip in rain-fed crops support with irrigation (+)	+				+					2	-	2
38	Farm HH's particip in *Belg* production (+)	+	-			+	+				3	1	4

Source: own organization

Notice: In Table 89, the column numbers (1-9) represent, (1) =Determinants of barley income (Eth. Birr), (2)=Determinants of fertilizer adoption (Kg), (3)=Determinants of HHs' aggregate income intensity (Eth. Birr), (4)= Determinants of HHs' aggregate income status; (5) = Determinants of barley food availability (Kcal); (6) =Determinants of aggregate food availability (Kcal), (7)=Determinants of HHs' aggregate food availability status, (8)= Determinants of HHs' perception level; (9) Determinants of HHs' perception intensity (mean perception) respectively;

Annex 5. Figures (Figure 10 and Figure 11)

Figure 11 (Annex). Focus group discussion and participants in qualitative data collection

Source: photo taken during the field work for data collection

Annex 6. Data Collection methods (Questionnaire & Focus group Discussion check list)

Survey Questionnaire (semi structured questionnaire)

This interview schedule is prepared to collect the primary data from farm households on their barley technologies adoption and its determinants, on the contributions of barley technologies adoption to farm households' income and food availability, on farm households' perception towards agricultural extension service and determinants in the study area, Semen Shewa Zone (Amara Region), in wortedas (Badsona, Ankober and Angollela).The data will be used for the research to fulfill the academic requirement (PhD-degree). It is with the hope that result of the study can be used for policy making, further research, and development program and strategy designing. Hence, your cooperation for adequate and quality information is indispensable. Except the aggregate output of the study, the confidentiality of your information will be maintained; no information will be hand over or shared to other third party without your awareness. Therefore, we kindly request your cooperation and genuine information provision. Therefore, we would like to thank you in advance for all of your cooperation.

General Direction to complete the questionnaire

Most of the questions in this questionnaire have alternatives to be chosen; and other questions have blank space to be filled with respondents' opinion. Therefore, each question should be answered based on the instructions given;

I. <u>Questions on location and personal background of respondents</u>

1.Respondents code No.………………………………and Name …………………………)
2.Respondent's Kebele No/name ……………. Sub Kebele No/name…………….... Village Name of the respondent……………………………………………………….…
3. Respondent's age …. year; and in year category (1) 18-30, (2) 31-45, (3) 46-65, (4) 66 and above
4. What is the HH size in age category? (1) Below 15 years, (2) between15-65 years, 3) 66 and above years….
5. Household size in number….; and in category (1) 1-3, (2) 4-6, (3) 7-9, (4) 10 and above
6. Household size in adult equivalent….; and in dependency ratio…… (done by researcher
7.Marital status: (1) Married, (2) Unmarried, (3) Divorced, (4) Widowed
8.Household head education status: (1) unable to read and write, (2) read and write/and or below grade 5, (3) grade five and above
9.The highest educational level in the household: (1) Read and write/and below grade 5, (2) grade 5-12 (3) above grade 12

II. Households' Resource ownership

10. What are the household's income sources? (1) crop sell, (2) from crop byproduct sell, (3) from livestock sell, (4) from livestock by product sell, (5) from cow dung, (6) from on farm labor work, (7) from off farm labor work, (8) from government support, (9) from NGOs support, (10) remittance (support from family live outside the country), (11) from family support live in the country, (12) from hay, pasture and straw sell, (13) if others, (please specify) …………………

11. Please tell me your land ownership based on the list in the table below;

No.	Household's own land resources and its utilization	Land size owned by households		Percent share from the total
		Measurement units		
		Paired oxen days	Hectares	
1	Farm land			
2	Grazing land			
3	Homestead land			
4	Forest land			
	Total land			100%
5	Farm land cultivated using (Meher, Belg and Irrigation) in 2005/2006			
6	Farm land cultivated using Belg rain season			
7	Farm land cultivated using Meher/Kiremt rain season			
8	Belg farm land cultivated in 2006			
9	Barley farm land from total Belg farm land in 2006			
10	Meher farm land cultivated in 2005/2006			
11	Barley farm land from total Meher farm land in (2005/2666)			

12. Does the household rent out farm land to others for cultivation? (1) yes (2) no
13. If yes, which type of farm land the household rented in (possible to choose more than one)? (1) Meher farm land, (2) belg farm land, (3) irrigation farm land
14. Does the household rent in farm land from others? (1) yes (2) no
15. If yes, which type of farm land the household rented out (possible to choose more than one)? (1) Meher farm land, (2) Belg farm land, (3) Irrigation farm land,
16. Which one is true about the household's practice of barley production? Choose one, (1) produce by rented in farm land, (2) not produce by rented in, (3) produce by rented out, (4) not produce by rented out
17. If the household produce barley by rented in the farm land, on which season (possible to choose more than one)? (1) Meher, (2) Belg, (3) Irrigation land
18. If the household produce barley by rented out the farm land, on which season (possible to choose more than one)? (1) Meher, (2) Belg, (3) Irrigation land
19. Pleas choose the production the household produced in 2013/2014? (possible to choose more than one): 1) wheat, (2) barley, (3) oats, (4) Sinar, (5) teff, (6) beans, (7) peas, (8)

lentils, (9) cick pea, (10) Adenguare, (11) food vetch, (11) Noug, (12) Flax, (13) fenugreek, (14) vegetables, (15) fruits, (16) others, (specify)…………………………

20. Please show the household's cereal crop production in different production season in 2013/2014 in kg, kcal and Eth. Birr;

No.	Cereal Crop	Meher		Belg		Irrigation		Total					
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	wheat												
2	teff												
3	Barley												
4	rice												
5	oats												
6	maize												
7	sorghum												
8	millet												
Total													

21. What is the total income of the household from pulse crops produced in different production seasons, in 2014/or 2006EC? Please indicate in the table below;

No.	Pulse Crops	Meher		Belg		Irrigation		Total				Price	
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	Faba bean												
2	pea												
3	Chick pea												
4	Lentils												
5	Food vetch												
6													
Total													

22. What is the total income of the household from pulse crops production of different production seasons Please indicate in the table below;

No.	Oil seeds	Meher		Belg		Irrigation		Total					
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	Flax												
2	Noug												
3	sunflo wer												
4													
Total													

23. What is the total income of the household from roots and tuber crops produced in different production seasons? Please indicate in the table below;

No.	Roots and Tubers	Meher		Belg		Irrigation		Total					
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	Potato												
2	Red-Onion (Shallot)												
3	White-Onion (Garlic)												
4	Beet root												
5	Karrot												
Total													

24. What is the total income of the household from vegetable crops produced in different production seasons? Please indicate in the table below;

No.	Vegetable crops	Meher		Belg		Irrigation		Total					
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	Tomato												
2	cabbage												
3	pepper												
4	spinach												
5	Orchard												
	Total												

25. What is the total income of the household from fruit crops produced in different production seasons, in 2014/or 2006EC? Please indicate in the table below;

No.	Fruit crops	Meher		Belg		Irrigation		Total					
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	orange												
2	Banana												
3	papaya												
4	lemon												
5	*Tringo*												
6	Others….												
	Total												

26. Please tell me the total farm land, production and income of the household from different crop production in different seasons, during2013/ 2014, based on the below table;

No.	Crop types	Meher		Belg		Irrigation		Total					
		ha	kg	ha	kg	ha	kg	ha	%	kg	%	Eth. Birr	%
1	cereals												
2	pulses												
3	oilseeds												
4	Roots and tubers												
5	vegetables												
6	fruits												
	Total												

27. Which production season does the household involve? (possible to choose more than one) (1) Meher, (2) Belg, (3) Irrigation
28. Which season does the household use to produce barley? (possible to choose more than one): (1) Mehere, (2) Belg, (3) Irrigation
29. Does the household practices livestock share-in from others? (1) yes, (2) no
30. Does the household practices livestock share-out to others? (1) yes, (2) no
31. Does the household produce livestock by products, in 2014? (1) yes, (2) no
32. If yes, for which purpose the household used livestock byproducts? (1) for income, (2) for food, (3) others (specify) ………………………………………………….
33. What is the household's livestock ownership in 2014? Please indicate based on the list in the table below;

Livestock owned by the household	Total livestock ownership and price estimate			Total number of livestock sold		Livestock owned by the household	Livestock ownership in number and in TLU			Total number of livestock sold	
	In	In	Eth.	In	Eth.		In	In	Price in	In	Eth. Birr

	number	TLU	Birr	TLU	Birr		number	TLU	Eth.Birr	TLU	
oxen						goats					
cow						horse					
bull						mule					
heifer						donkey					
Calf (male/female)						chicken					
sheep						Honey Bees in beehives /colonies					
Total livestock resource						Total livestock resource					
The annual total income from livestock sell in 2013/2014					________+____________= ____________________						
The household's total monetary value of livestock resource in 2014					______+_______=_________Eth. Birr____________						

34. What is the household's livestock by product, production, consumption and income, in 2013/2014? Please indicate in the table below;

Types of Livestock by product	Unit measurement	Total production (Quantity)	%	Unit price (Eth. Birr)	Total price (Eth. Birr)	%	for household consumption			for sell	
							Quantity	Kcal	%	Quantity	Eth. Birr
Milk sell	Lit/kg										
Cheese sell	kg										
Butter sell	kg										
Other milk by products sell	Li/kg										
Honey sell	kg										
Meat sell	kg										
Egg sell	No.										
Wool sell	Kg										
Skin and hide sell	Pcs										
From animal rent	Eth. Birr										
Cow dung sale	Eth. Birr										
Total benefits the household got from livestock by product in 2013/2014											

35. Does the household use improved technologies in 2013/2014? (1) yes, (2) no
36. If, yes, what are the technologies the household used (possible to choose more than one)? (1) fertilizer, (2) improved seed, (3) improved vegetable, (4) improved fruits, (5) improved livestock breeds, (6) improved forage seeds, (7) row plantation, (8) improved irrigation, (9) pesticide, (10) weedicide, (11) others (specify)…………………………
37. Does the household produce barley in 2013/2014/? (1) yes, (2) no
38. If yes, does the household use improved technologies to produce barley? (1) yes, (2) no
39. If the household used improved technologies to produce barley, what were those technologies? (1) fertilizer, (2) improved seed, (3) row plantation, (4) pesticide, (5) weedicide, (6) improved irrigation, (7) others (specify)……………………………
40. What is the fertilizer rate for barley production? In kg/ha…………………………...

41. What is the improved seed rate for barley per hectare in kg?....................................
42. What is the weeding frequency for barley? (1) one time, (2) two times, (3) three times, (4) four and above
43. What is the plowing frequency for barley? (1) one time, (2) two times, (3) three times, (4) four and above
44. What are the criteria the household use to select and grow barley varieties? Please, indicate the criteria the household used from the list in the table below;

No	Improved barley varieties grown by HHs	Rank	Selection Criteria					
			For its better market price	For its food quality	For its productivity	Disease/ pest resistance	Frost resistance	Climate adaptability
1								
2								
3								
4								
5								
6								
No	Local barley varieties HHs grown	Rank	Selection Criteria					
1								
2								
3								
4								
5								
6								

45. Does the household, get seed support from other sources in addition to its own sources in2014/or 2006 EC? (1) yes, (2) no
46. Please, indicate in the below table, all seeds sources of the household including its own, in 2013/2014

No	Types of seed the household use	Own seed source		Government aid /support		NGOs		Borrowing		Relatives support		Total		
		Kg	Eth. Birr	kg	Eth. Birr	kg	Eth. Birr	kg	Eth. Birr	kg	Eth. Birr	kg	% share	Eth. Birr
1	wheat													
2	Teff													
3	Barley													
4	Maize													
5	sorghum													
6	millet													
7	lentils													
8	Beans													
9	pea													
10	vegetables													
11	Root crops													
12	fruits													
	Total													

47. From where the household cover the 2014 food requirement (possible to choose more than one)? (1) from own production, (2) from Aid, (3) purchasing, (4) from relative gifts

48. If the household got the aid, please show from which institution the household get the aid using the table below;

No.	Food types	Food aids the household obtained from different sources												
		From Government		From NGOs		From community		From relatives support		Total				
		kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	Eth. Birr
1	wheat													
2	barley													
3	maize													
4	sorghum													
5	Rice													
6	Beans													
7	peas													
8	Haricot bean													
7	lentils													
8	chickpea													
9	Food oil													
	total													

49. Does the household purchase food in 20013/2014? (1) Yes, (2) No

50. If the household purchased food in 2013/2014, please mentioned them based on the following table to indicate the purchased food items (first the weekly purchased and can be convert to annual)

No.	The types of food items purchased	Quantity		
		kg	kcal	Eth. Birr
1	wheat			
2	barley			
3	teff			
4	Oats (Aja)			
5	Sinar (ስናር)			
6	maize			
7	sorghum			
8	Millet			
9	bean			
10	peas			
11	chickpeas			
12	lentils			
13	Boleke (ቦሎቄ)			
14	Adenguare (አደንጉዋሬ)			
15	Food vetch			
16	flax			
17	Noug			
18	sunflower			
19	pepper			
20	onion			
21	cabbage			
22	spinach			
23	orchard			
24	tomato			
25	potato			
26	karot			
27	beetroot			
	Total			

51. Does the household have experience of money saving? (1) yes, (2) no

52. If yes, which saving institution use the household used to save its money? (1) Bank, (2) cultural saving, (3) in cooperatives

53. When does the household starts to save its money? ………………………………………

54. From the following lists of the home items, please indicate which one the household has? Use the (✓)mark please;

No.	House items	Yes	No	No	Home items	Yes	No
1	Sewing machine			7	Mule/horse for transport		
2	House with iron sheet			8	Radio		
3	Modern bed			9	Tape		
4	Home at town			10	Television		
5	Labor worker			11	mobile		
6	Home worker			12	Grain mill		

55. What is the 2013/2014 household's expenditure can be estimated? Please indicate in the below table;

No	HH's expenditure list	Eth. Birr	%	No.	HH's expenditure	Eth.Birr	%
1	To purchase cloth			9	Livestock purchase		
2	To purchase cereals			10	To purchase forage		
3	For pulses purchase			11	For inputs purchase		
4	To purchase food oil			12	daily laborers payment		
5	To purchase root crops			13	For tax payment		
6	To purchase vegetables			14	To pay loan		
7	For fruits food purchase			15	Education fee		
8	To purchase seed			16	Health fee		
Total expenditure							

56. Is there a difference in food consumption among household members? (1) yes ፣ (2) No

57. If there is a difference in food consumption among household members, among whom the difference is? (1) among children and adults, (2) among men and women, (3) among all

58. To which household members are barley used for food? (1) for adults, (2) children, (3) for all

59. At what feeding schedule barley is commonly eaten? (1) breakfast, (2) launch (3) Dinner

60. In what form barley is eaten? (1) solid food form, (2) liquid form, (3) both

61. Which food form does the household use barley for food? (1) Enjera, (2) Kita, (3) kolo, (4) Genefo, (5) Kinch, (6) Besso

62. From drinking form, which one is consumed /used by the household? (1) Tella, (2 Bukri, (3) Alke, (4) Besso Shamete

63. Does the household sell barley? (1) yes, (2) No

64. If the household sell barley, why? (possible to choose more than one); (1) because it is surplus, (2) to cover other expenses of the household, since there are no other options, (3) to exchange other food varieties for the household

65. Does the household have an experience of reserving barley for other time? (1) yes, (2) No

66. If the household does not have experience to reserve barley for the time if there may be scarcity, what is the reason? (1) Low production that is not surplus, (2) because it is spoiled, (3) if others (specify)…………………………………….

67. Does the household use improve agricultural technologies in 2013/2014? (1) Yes, (2) No

68. If yes what technologies the household used in 2013/2014, what are they? (1) artificial fertilizer, (2) improved crop seeds, (3) improved vegetable varieties, (4) improved fruit varieties, (5) improved root crops, (6) improved forage species, (7) improved livestock breeds, (8) improved beehives, (9) improved irrigation, (10) row plantation, (11) compost (12) others ………….

69. How much chemical fertilizer, the household used in 2013/2014? ……………….kg. (DAP----------kg and Urea……….kg)
70. For how many years the household have been used improved agricultural technologies? ....years
71. What is the household's improved agricultural technologies utilization? (1) continuous use, (2) discontinued
72. If discontinued, what was the reason? (1) Improved technology scarcity, (2) credit scarcity, (3) others ………………………….
73. Does the household produce barley use improved agricultural technologies? (1) yes, (2) no
74. If yes, for how many years does the household use improved agricultural technologies to produce barley? …………. years
75. What are the improved agricultural technologies used to produce barley? (possible to choose more than one) : (1) chemical fertilizer, (2) improved seed, (3) pesticide, (5) weedicide, (6) row plantation, (7) improved irrigation technologies (8) compost
76. How much farm land the household cultivated using compost in 2013/2014? __hectares
77. How much barley land the household cultivated using compost in 2013/2014?......hectares
78. To increase crop production which one is better from chemical fertilizer and compost? (1) chemical fertilizer is better than compost, (2) compost is better than chemical fertilizer, (3) I do not know
79. Does the household get extension service? (1) Yes, (2) No
80. If the household get extension services, from which institution the household get the services? (1) from government/public, (2) from NGOs, (3) from both
81. Which extension service does the household get? (1) On farm, (2) through training፣ (3) tour and visit, (4) through demonstration, (5) if others, (specify)…………………………
82. What is the weekly base extension contact? (1) one time, (2) two times, (3) three times, (4) four and above
83. Did the household get extension service on barley production? (1) yes, (2) No
84. If, yes, what were the extension services the household get on barley production? (1) how to select improved seed, (2) on seed rate, (3) fertilizer application, (4) on improved agronomic practices, (5) on postharvest, (6) on value chain and marketing of barley, (7) on row plantation, (8) how to use pesticide, (9) how to use weedicide
85. Which input the household use in 2013/2014? (possible to choose more than one) :(1) chemical fertilizer, (2) improved seed, (3) pesticide, (4) weedicide, (5) improved storage, (6) compost, (7) improved livestock breeds, (8) rain water harvesting structures, (9) improved irrigation, (10) improved beehives
86. Was the household used credit inn 2013/2014? (1) yes, (2) No
89. If the household was not used credit, how the household solve the financial problem? (possible to choose more than one): (1) own saving, (2) from government gifts, (3) from NGOs gifts, (4) from relative's gifts 5) from community gifts
90. If the family used credit, from which institution did the household took credit? (possible to choose more than one): (1) Govnm't, 2) NGOs, (3) cooperatives, private lenders
91. For what purposes the household used the credit? (1) to buy inputs, (2) to buy livestock, (3) to buy oxen, (4) to cover the household's expenses, 5) to pay the loan, (6) education fee, (7) for health expenses
93 How far the residence of the household from credit providing institution?...................km

94. In what form the household take credit to produce barley? (possible to choose more than one) taken? (1) in financial form, (2) in kind, (3) both
95. For what purposes the household used the credit? (1) to buy fertilizer, (2) to buy improved seed, (3) to buy pesticide, (4) to buy weedicide, (5) to pay for daily laborers
96. The household uses barley as income source? (1) by producing, (2) by involving in barley trade, (3) all
97. Why the household sell barley? (1) Because, the production is surplus, (2) for exchange of other food varieties for the household, (3) for investment, (4) if others (specify)……...
98. What values are the household adding to sell barley? (Possible to choose more than one): (1) storage, (2) transport, (3) prepare barley in local drink form, (4) prepare barley in different solid food form, (5) cleaning, (6) others (specify)……………………………
99. Where is the market place the household use to sell barley? (1) open market, (2) retailers, (3) traders/collectors, (4) whole sellers, (5) for consumers
100. What are the means of transportation the household use to take barley to the market place? (Possible to choose more than one)? (1) animals, (2) human (3) vehicles
101. What types of road the household use to transport barley to the market place? (1) asphalt, (2) all weather road, (3) dry season road
102. What is the amount of barley sold by the household in 2013/2014 in kg? --------------kg
103. Farm household's perception towards agricultural extension service in the study area; please use the mark (✓) to show your agreement to each question shown in the below table.

No.	Perception Items/Statements on agricultural extension services	Perception categories				
		Strongly disagree (1)	Disagree (2)	Undecided (3)	Agree (4)	Strongly Agree (5)
1	The extension advice service is low (weak) to improve farm HHs' skills and knowledge					
2	The role of agricultural extension to improve agricultural production is low					
3	The training given by agricultural extension for the farmers is important to improve agricultural production					
4	Agricultural extension gives adequate time to advice farm HHs on the use of improved agricultural technologies					
5	Agricultural extension advice does not consider the farm households interest					
6	Organizational structure and arrangement of agricultural extension is not strong to give appropriate extension service					
7	The agricultural extension professional competency to disseminate appropriate extension service is not satisfactory and adequate					
8	The Agri. extension office is far for the majority of farm HHs					
9	Agricultural extension service does not focus on timely agricultural activities					

Focus Group Discussion Checklist

1. The importance of barley for the farm households and problems to improve its production
2. Opinions on the importance of adoption of fertilizer, pesticides, weedicides, and improved barley seeds, in farm households' income and food availability;
3. Improved agricultural inputs cost, availability, adequacy and quality to use and enhance yield, thereby, income, food availability;
4. Comparison of the importance of fertilizer with that of manure compost;
5. Credit and extension services accesses, roles and problems related to the services;

Annex 7. Focus Group Discussion Opinions Summary

- ❖ Barley in the highlands of Semen Shewa is the most important crop among other crops, it is because its resistance and adaptability with the highland environmental conditions such as frost. As a result, farm households have higher experience and indigenous knowledge in managing and producing barley;
- ❖ Barley in Amharic is called as *Gebse*, to show its' importance and superiority in the area, ***Gebse yeihil Niguse***. It is because barley is high energy providing food crop, good for health, well perform and provide better yield in the highland area than other crops, because of its resistance and adaptability nature. Without barley, it is difficult to lead life in the highland areas without barley;
- ❖ In the highland area, children start food by eating food prepared from barley (important to children to exercise food than other crops), which is suitable and healthy for children;
- ❖ It is used to prepare different food types such as eating and drinking food types that include; (i) eating forms of barley food types include (Injera, Kita, Tiresho, Chicko, Chechebsa, Genfo, Kinche, Besso, Kollo, Gebse-eshet, enkuto); (ii) Drinking food types include (Muk/Atmit, Shameta prepared from Busso); and Local/home Beverages include (Tella, Areke, Bukri, Keneto);
- ❖ Barley can also use for sale to bring income for the household;
- ❖ Straw for livestock feed and house wall construction by mixing it with mud) and its stems for house roof thatching;
- ❖ Improved varieties of barley that much not important, because of frost and pest resistance. It is also costly for the farm households to purchase and use;
- ❖ Other inputs' costs also very high that most of the benefits from use of them is used to pay their price;
- ❖ The quality of the inputs is poor as compared to the previous inputs. For example, Fertilizer during the imperial and Derg regime, the quality of fertilizer was high as

compared to the EPDRF time. When the farmers' sow fertilizer during the Imperial and Derg time, farmers' hand became oily; but during the current government fertilizer is full of dust. Hence, when farmers sow it, their hand/arm become full of dust. Even though it is poor in quality, its price also surprisingly too high.

- Regarding the timely availability, and adequacy, it is not satisfactory;
- The credit service in the study area is full of constraints such as collateral problem, group borrowing problems, extremely high interest rate, time of repayment (during harvest time that time is the time when agricultural products are cheap that extremely discouraging farmers, it is because the majority of the farm outputs are used for repayment of the credit and its high interest rate. Some farmers sell their oxen or cow, horse or mule and other assets. As a result, credit due to these problems is called in the study area in Amharic "***Amenmin***" since farmers' asset reduced for credit payment that thin households' assets;
- Livestock dung is very important in increasing soil fertility, in soil mass and the compost used this year can improve the soil fertility, thereby, yield at least for 3 years, but not possible in the case of fertilizer. In the study area, it was raised by the participants that husband and wife always quarreled by livestock manure that the husband want it to use for soil fertility; while the wives want to use for fuel to prepare food since there is no other energy options. The husbands always call the livestock dung/the manure, *yelijoch gebse;*
- Extension service, in terms of credit problem, inputs cost, adequacy, timely availability, and in terms of quality is poor, while in advising, accessing information and in follow-upping/supervising, in supporting to use some improved practices is fairly good;
- In the study area, no households pass a day without consuming barley. In every household, except the difference in quantity, barley is available for daily consumption. Therefore, barley is very important; but its yield is very low. To improve, its yield improving the quality of inputs such as fertilizer, and reducing the interest rate of credit, collateral problem, group borrowing problem and repayment time should be solved;
- The Focus Group Discussion participants described that barley is their life, without it life is difficult for them. Because, other crops cannot successful provide as barley the required food and other life necessities for them. It is because, barley is a well-adapted and well performed crop in the area.