

**DETERMINANTS OF ADOPTION OF IMPROVED *TEFF*
VARIETIES BY SMALLHOLDER FARMERS: THE CASE OF KOBO
DISTRICT, NORTH WOLLO ZONE, AMHARA REGION, ETHIOPIA**

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**Determinants of Adoption of Improved *Teff* Varieties by Smallholder
Farmers: The Case of Kobo District, North Wollo Zone, Amhara Region,
Ethiopia**

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As research advisor, I hereby certify that I have read and evaluated the thesis prepared by Susie Teshome Belay under my guidance, which is entitled “**Determinants of Adoption of Improved *Teff* Varieties by Smallholder Farmers: The Case of Kobo District, North Wollo Zone, Amhara Region, Ethiopia**”. I recommend that the thesis be submitted as it fulfills the requirements.

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I dedicate this thesis manuscript to my beloved families and my best friends for their affection, love and dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author was born in Habru District in North Wollo Zone on 03 November, 1991. He completed his primary school at Sirinka town. Then, he attended his secondary and senior secondary education at Woldia secondary school in Woldia town.

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ACRONYMS AND ABBREVIATIONS

ATA	Agricultural Transformation Agency
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
ETB	Ethiopian Birr
GDP	Gross Domestic Product
Ha	Hectare
HYV	High Yielding Varieties
MHH	Male Headed Households
MoA	Ministry of Agriculture
OKARD	Office of Kobo Agricultural and Rural Development
SARC	Sirinka Agricultural Research Center
TLU	Tropical Livestock Unit
USD	United States Dollar
VIF	Variance Inflation Factor
WB	World Bank

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Determinants of Adoption of Improved Teff Varieties by Smallholder Farmers: The Case of Kobo District, North Wollo Zone, Amhara Region, Ethiopia

ABSTRACT

Adoption and wider diffusion of improved teff varieties is playing vital role in reversing the present situation of food insecurity in many parts of Ethiopia. However, the uses of improved teff varieties are constrained by various factors. Hence, in this study, an attempt was made to examine factors affecting adoption and intensity of use of improved teff varieties. A multi-stage random sampling technique was employed to select 150 sample households from Kobo district. This study used cross-sectional data collected in 2015/16 production season from sample households. Descriptive statistical tools like mean, standard deviation, percentage, and frequency distribution were used to summarize the characteristics of the sampled households. Double-hurdle model was used to identify factors influencing households' adoption decision and intensity of use of improved teff varieties. The result of double-hurdle model shows that educational level of household head, participation on crop production demonstration, distance from the nearest market, frequency of extension contact, off/non-farm income, proportion of cultivated land allocated for teff, livestock holding, improved teff seed availability, and perception on better yielding capacity of the new varieties over local varieties were found to be significantly influencing households adoption decision, whereas, sex, age, family labor, membership to an organization, off/non-farm income, frequency of extension contact and proportion of cultivated land allocated for teff were found to be significantly influencing the intensity of adoption of improved teff varieties. Therefore, this result implies that strengthening the existing extension services, providing good transport facilities for farmers through infrastructural development, improving access to improved seeds, improving farmers' level of education, strengthening farmer's organization, encouraging the use of labour saving technologies, improving crop-livestock production system and provision of demonstrations of new technologies are areas that need policy attentions to enhance adoption and intensity of use of improved teff varieties. Further, high yielding teff varieties need to be given special priority in teff variety scaling out programs.

Key words: Adoption, Improved teff varieties, Double-hurdle model, Intensity, Kobo

1. INTRODUCTION

1.1. Background of the Study

Ethiopia is fundamentally an agrarian country and agriculture is Ethiopia's most important sector, crucial for the country's food security and the livelihoods of its people. The sector is the largest contributor to the overall economy and is fundamental to Ethiopia's overall development. Despite the dominance of traditional smallholder farmers in the sector, increased engagement with mid and large-scale private sector partners has brought new technologies and improved market linkages (ATA, 2014). Although the transformation towards a more manufacturing and industrially oriented economy is well underway, the agriculture sector continues to be the most dominant aspect of the Ethiopian economy, accounting for nearly 42% of GDP, 85% of employment, and 90% of foreign export earnings (CSA, 2016).

Despite of its contribution to the national GDP by large, agriculture in Ethiopia is subsistence. Smallholder farmers are cultivating 95% of their farmland (Atsebaha and Tessema, 2014) using mostly traditional farming practices and inadequate improved technology be found in the low productivity Ethiopian agriculture (Zerihun *et al.*, 2014). Furthermore, the majority of the agriculture sector is made up of smallholder farmers who live on less than 1.17 hectares of land (WB, 2013). This is particularly true to the major food crops grown in the country.

Major crop categories include cereals, pulses and oilseeds, which are not only constituted the major food crops for the majority of the country's population but also served as a source of income at household level and a contributor for the country's foreign currency earnings. In Ethiopia, cereals are the major food crops both in terms of area coverage and volume of production. For instance in 2015/16 production season cereals accounted for about 11.3 million ha (80.78% of the total grain cultivated land) and about 27.1 million ton (86.08% of the total national grain production) (CSA, 2016).

Teff is one of the cereals grown in most agro-ecological zones of Ethiopia and mainly used for food consumption. It ranks first in area coverage and second after maize in total production. The crop accounted for about 28.7% of the total grain cultivated land (CSA, 2016). It is a multipurpose crop, being utilized in different forms where the grain is used to make the

Ethiopian staple food, *Injera*. It is also valued for its fine straw, which is used for animal feed as well as for reinforcing mud for plastering wooden walls of buildings (Bekabil *et al.*, 2011).

The popularity of *teff* can be also explained with its high price. It is the highest priced cereal grown in Ethiopia and is an attractive cash crop for farmers. Combined with the high share of the final price obtained by the farmers, income from *teff* is much higher than income from other cereals and even 34% higher than income from coffee, the major export crop in Ethiopia (Minten *et al.*, 2013; Worku *et al.*, 2014). About 25-30 million people are directly depend on *teff* production. The higher *teff* price followed by an increasing commercialization of smallholder farmers represents an opportunity to directly increase the living standard of rural communities in Ethiopia (Hauenstein, 2015).

In Ethiopia, adoption of improved agricultural technologies by smallholder farmers has been a long-term concern of agricultural experts, agricultural research and many others linked to the sector for increasing production and income. However, adoption rate of modern agricultural technologies in the country is very low (Berihun *et al.*, 2014).

The use of improved variety is considered as an important input for the achievement of increased agricultural productivity and food security status of farm households in Ethiopia. In this regard, there has been an increasing effort to improve crop productivity primarily through agricultural intensification, involving an increased use of inputs, including seeds of improved crop varieties (Byerlee *et al.*, 2007). *Teff* is also considered as a priority crop by the national extension program of the MoA due to its significance in food security and commercialization. In order to promote the adoption of improved varieties in smallholder farmers, a number of extension activities have been done in the major *teff* growing areas of the country (ATA, 2013). In line with this, nearly thirty two improved varieties were released by EIAR (MoA, 2010). The research-extension program of the national agricultural research system played key role in the dissemination of improved *teff* varieties through on-farm verification and demonstration (Setotaw, 2013).

Setotaw (2013) showed the presence of significant gap between the potential *teff* yield and the actual farmers' yield. This is due to low adoption of available improved varieties by smallholder farmers. There has been a wider consensus that, the weak seed system in Ethiopia is also one of the limiting factor for the slow dissemination and low rate adoption of improved *teff* varieties

since the formal seed sector which consists of both the private and public seed enterprises is driven by profit. In Ethiopia, the formal seed sector covers only 5% of the *teff* seed requirement (Dawit *et al.*, 2007).

There are different stakeholders participating in the regional farmers based improved *teff* varieties or seed multiplication; the Amhara Agricultural Research Institute (ARARI), SARC, OKARD, NGO's and the farmers themselves. In Kobo district, improved *teff* varieties are being promoted by the government. However, study on the adoption and intensity of use of these improved varieties were not conducted in the study area so as to know the gap. In order to improve production and productivities of *teff*, identifying factors affecting adoption and intensity of adoption was found to be important. Therefore, this study was initiated to identify determinants of adoption and intensity of adoption of improved *teff* varieties in Kobo District of Amhara Region.

1.2. Statement of the Problem

Most developing economies are characterized by heavy dependence on rain fed agriculture, traditional type of farm practices, low adoption rate of technology and farm inputs, poor infrastructure facilities including roads, transport, marketing, higher labor to capital ratio and low farm productivity (Berhane, 2009; Alemitu, 2011; Susan, 2011). Ethiopia is one of the developing economies which is not realizing its full agricultural potential, as the sector is dominated by subsistence oriented, low input/low output and rain-fed farming systems. Ethiopia's agricultural produce is also limited in production diversity (WB, 2008). On the other hand, agriculture is the main source of livelihood for the majority of the population particularly for peoples residing in rural areas (Schmidt and Kedir, 2009).

Throughout the world, for many decades, smallholder and commercial farmers have been steadily increasing their production through adoption of productivity enhancing agricultural technologies and thereby making production more efficient. Technological advancements have soared exponentially, providing opportunities for farmers to maximize profits and efficiencies (WB, 2016). In Ethiopia, however, access to and adoption of new agricultural technologies have been greatly limited by socio-economic, logistical and institutional obstacles (Mekuria, 2013; Minten *et al.*, 2012).

Teff is a staple food crop for most households in rural and urban areas of Ethiopia which consist of more than 65% of the population (CSA, 2013). It has the largest value in terms of both production and consumption in Ethiopia and the value of commercial surplus of *teff* is second only to coffee (Minten *et al.*, 2013). It is also the main source of income and employment for the majority of rural households. The crop accounts for approximately 12.7% of all calories consumed (Kaleab, 2014).

Despite its economic importance in Ethiopia, the productivity of *teff* remains low. For instance, in 2015/16 production year, *teff* yield was 15.60 qt/ha, significantly lower than other cereals, such as maize (33.87 qt/ha), sorghum (23.31 qt/ha) and wheat (26.32 qt/ha) (CSA, 2016). The low *teff* yield is apparently explained by the limited knowledge about the possible avenues for improving *teff* productivity, together with the problems inherent to its botany. Moreover, *teff* yield is low because of lodging, low modern input use, traditional way of sowing, socio-economic factors such as lack of access to market information, post-harvest and processing losses and lack of high yielding cultivars (Bekabil *et al.*, 2011; Tareke *et al.*, 2011).

In order to increase the production and productivity of agricultural output, to raise income and to enhance food security, the uses of improved agricultural inputs are very important out of which high yielding crop variety is very essential (Tsegaye and Bekele, 2012; Setotaw, 2013; Berihun *et al.*, 2014). Consequently, in Ethiopia, to increase the productivity of *teff* several improved varieties were developed and disseminated to farmers along with their optimum management practices (Setotaw, 2013). However, different area-specific evidences indicate that intensity and adoption rate of improved *teff* varieties in the country is low. This low rate of adoption decisions of farmers is usually determined by various factors which can be specific to socio-economic, institutional, demographic and psychological. In addition, factors such as expensiveness and unavailability of seeds and desired varieties, lack of awareness and the serious sequence of agronomic practices have commonly been mentioned as the constraints contributing to the low level of improved *teff* varieties adoption (Tesfaye *et al.*, 2001; Hailu, 2008; ATA, 2012).

The study area, similar to many parts of Ethiopia, is mainly characterized by rugged topography, unreliable rainfall condition, and risk prone farming systems. As a result, crop production has become highly unpredictable and substandard throwing the major proportion of the rural

population in to food insecurity situation (SARC, 2015). Apparently, agricultural performance in the area should be improved if the food security of the majority of farmers is to be enhanced. Hence, improvement, dissemination and adoption of improved *teff* varieties have an invaluable role in reversing the present situation of food insecurity in the study area. As part of this goal, in the study area improved *teff* varieties are often introduced in a package program although adopters use part of the package.

In spite of such intervention, information with regard to adoption of improved *teff* varieties on location specific factors influencing adoption and intensity of adoption of improved *teff* varieties being promoted in the districts was not systematically and empirically studied and documented. Hence, this study was aimed at analyzing factors that influence the adoption decision and intensity of adoption of improved *teff* varieties in order to draw important conclusions and policy implications for future intervention.

1.3. Scope and Limitation of the Study

The study was delimited to Kobo District of the Northern Wollo administrative Zone. Therefore, the study has limited coverage from the zone in particular and from *teff* growing areas of Wollo in general. This study was confined only to the determinants of adoption and intensity of use of improved *teff* varieties at farmers' level. Moreover, one crop namely *teff* is selected for this study due to its importance for domestic food consumption and commercialization in Ethiopia. The limitation of this study is related to the types of data collected. The study mainly utilized cross-sectional data generated from the sample household survey of only one cropping season and was not also incorporate information generated from farming plot characteristics. The analyses of this study was largely based on static models, in which adoption decision process treated as a static phenomenon and issues of expectations and dynamic adjustments are ignored. This wouldn't enable the study to capture various dynamisms of the subject under interest.

1.4. Significance of the Study

Teff is the major staple cereal crop in the study area. Hence to increase production and productivity of the crop, adoption of improved varieties is an important agricultural policy issue. The study analyzes the adoption and intensity of use of improved *teff* varieties in Kobo district.

Therefore, this study can help to identify factors influencing adoption decision and intensity of adoption of improved *teff* varieties in the study area. In addition, the significance of this study lays ground to provide information for further improvement of the adoption of the varieties. The findings of this study is used as an input for policy makers in designing future policies and strategies for *teff*. Moreover, the study could serve as a document for other researchers and may also provide a base for other studies; that focus on similar topic and issues, related to the adoption of improved *teff* varieties in particular and other commodities in general. Hence, an investigation of the underlying factors associated with adoption of improved *teff* varieties will benefit local and regional governments, researchers, policy makers, extension workers, farmers and other stakeholders.

1.5. Research Questions

This study tried to answer the following research questions:

1. What are the factors determining the adoption of improved *teff* varieties in the study area?
2. What are the factors affecting intensity of adoption of improved *teff* varieties in the study area?

1.6. Objectives of the Study

The general objective of this study was to analyze determinants of the adoption of improved *teff* varieties: in Kobo District, North-Wollo Zone of Amhara Region, Ethiopia.

The specific objectives of the study were:

1. To identify factors affecting the adoption of improved *teff* varieties in the study area.
2. To analyze factors affecting intensity of adoption of improved *teff* varieties in the study area.

2. LITERATURE REVIEW

In this chapter, theoretical reviews of basic concepts and definitions, the origin and distribution of *teff*, production, economic importance and consumption of *teff* as well as theoretical framework that serve as a basis for the analyses are discussed. In addition reviews of relevant empirical literatures on adoption of agricultural technologies, analytical framework for adoption of agricultural technologies and overview of agricultural technology adoption in Ethiopia are discussed.

2.1. Basic Concepts and Definitions

The concept of technology adoption could be better conceptualized through understanding the difference between technology adoption and diffusion, which are highly interrelated but distinct concepts. Technology adoption is measured at one point in time while technology diffusion is the spread of a new technology across population over time (Thirtle and Ruttan, 1987).

While explaining the distinction between these concepts, Rogers (1983) argued that technology adoption as the use or non-use of a new or improved technology by an individual or farmer as best course of action practiced at a given period of time. On the other hand, technology diffusion (aggregate adoption) is defined as the process by which a technology is communicated through certain channels over time among the members of social systems. It signifies a group of phenomena, which suggests how technology spreads among users. This definition recognize the following four elements: (1) the technology that represents the new idea, practice, or object being diffused, (2) communication channels which represent the way information about the new technology flows from change agents (extension, technology suppliers) to final users or adopters for instance farmers, (3) the time period over which a social system adopts a technology, and (4) the social system.

Technology is the application of knowledge for practical purposes. Technology is used to improve the human condition, the natural environment, or to carry out other socio-economic activities (Swanson *et al.*, 1997). Technology can be defined as the knowledge or information that permits some tasks to be accomplished more easily, some service to be rendered or the

manufacture of a product (Lavison, 2013). Rogers (1983) also defines technology as an idea, practice, or object that is perceived as new by an individual or groups of a society.

Adoption is viewed as a variable representing behavioral changes that farmers undergo in accepting new ideas and innovations in agriculture. The term behavioral change refers to desirable change in the knowledge, understanding, and ability to apply technological information; changes in feeling behavior such as changes in interest, attitudes, aspirations, values and the like and changes in overt abilities and skills. Adoption is also defined as a decision-making process, in which an individual goes through a number of mental stages before making a final decision to adopt an innovation. Decision-making process is the process through which an individual passes from first knowledge of an innovation, to forming an attitude toward an innovation, a decision to adopt or reject, to implementation of new idea, and to confirmation of the decision (Ray, 2001).

However, as emphasized by Ray (2001) adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always be practiced by farmers to adopt new technology. Farmers may adopt the new technology by passing the trial stage. In some cases, particularly with environmental innovations, farmers may hold awareness and knowledge but because of other factors affecting the decision making process, adoption does not occur.

Adoption was also defined by Feder *et al.* (1985) as degree of use of new innovation by a farmer when he has got full information about the new innovation and its potentials. The author also defined adoption of new technology at the household level as the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology. In addition the author classified adoption of new technology into two as individual and aggregate adoption. Accordingly, they defined individual adoption as the farmer's decisions to incorporate a new technology into the production process and the aggregate adoption as the process of diffusion of a new technology within a region or population. Further, their studies distinguished technologies that are divisible and non-divisible. Divisible technology in terms of resource allocation requires the decision process to involve area allocations as well as levels of use of the rate of application (for instance, improved seed, chemical fertilizer, and herbicide and pesticide). Whereas, technologies that are not divisible in term of resource allocation require how much resource to be allocated to the new and old technologies (for instance, mechanization,

irrigation and better farm management practices such as uses of recommended agronomic practices).

As indicated by Dasgupta (1989) adoption is not a permanent behavior. Consequently, an individual may decide to discontinue the use of an innovation for a variety of personal, institutional or social reasons one of which could be the availability of an idea or practices that is better in satisfying his or her needs (Ray, 2001). On the other hand, although farmers often reject an innovation instead of adopting it, non-adoption of an innovation does not necessarily mean rejection. Farmers are sometimes unable to adopt an innovation, even though they have mentally accepted it, because of economic and situational constraints (Dasgupta, 1989).

The rate of adoption is defined as the percentage of farmers who have adopted a given technology over time. In addition to this, the proportion of sample farmers using improved technologies is used as a proxy to estimate the rate of the technology. On the other hand, the intensity of adoption is defined as the level of adoption of a given technological package. Put it in a different way, the number of hectares planted with improved seed also tested as (the percentage of each farm planted to improved seed) or the amount of input applied per hectare represent the intensity of adoption of the respective technologies (Nkonya *et al.*, 1997).

Agricultural technologies adoption can help increasing efficiency in a number of ways. The need for technology adoption in agriculture, besides increasing factors' efficiency, is to cope with natural hazards faced by the sector. Experiences of many countries showed that sizable proportion of agricultural technology is commodity specific (improved seeds and animal breeds) that are suited only for limited and usually most favorable ecological environments (Anderson, 2007).

2.2. Origin and Distribution of *Teff*

Teff (*Eragrostis teff* [Zucc.] Trotter) is an allotetraploid cereal crop grown primarily in Ethiopia. It is traditionally harvested crop in Ethiopia, where it was first domesticated between 1000–4000 BC even before the ancient introduction of other crops (Rose, 2011). It is entirely cultivated in Ethiopia and Eritrea as food crop and distributed to several other countries and grown on a limited basis a grass for livestock forage in Australia, India, Kenya and South Africa

(Costanza *et al.*, 1979; Piccinin, 2002). Intensive studies carried out on *teff* in USA universities initiated its cultivation for both grain and forage has begun in USA. Since 2003 *teff* has also been grown on several places in the Netherlands and is becoming an important health crop (Hopman *et al.*, 2008).

Vavilov (1951) identified Ethiopia as the center of origin and domestication for *teff* that is highly adapted to diverse agro-ecological conditions. It is endemic to Ethiopia and its major diversity is found only in that country as with several other crops. Most of the time *teff* is grown at middle elevations between 1,800 and 2,200 m.a.s.l and in regions that have adequate rainfall (Minten *et al.*, 2013). It can also be grown in low rainfall and drought prone areas characterized by prolonged growing seasons and frequent terminal moisture stress. The crop grows on various soil types ranging from very light sandy to very heavy clay soils. Moreover, it grows better on marginal soils. Cultivation of *teff* in Ethiopia has in part been motivated by its relative advantages over other cereals in the use of both the grain and straw (Miller, 2010).

Teff displays very broad and versatile adaptation and resilience to marginal environmental and cultural conditions with good tolerance to both low and high moisture stresses. It represents a unique biodiversity component in the agriculture and food security of millions of farmers in Ethiopia. The conservation, characterization, and utilization of the existing *teff* genetic diversity are becoming increasingly important in view of the evolving needs and manifold challenges of small-scale farmers in Ethiopia. This is primarily because *teff* has remarkable genetic traits useful for most Ethiopian farmers to utilize for coping with erratic climatic conditions and developing crop diversification in the moisture stress areas of the country. Central highlands of Ethiopia are the largest and major *Teff* production areas in the country (Kebebew *et al.*, 2011).

2.3. Production and Economic Importance of *Teff* in Ethiopia

Teff is an important cereal crop in Ethiopia providing the livelihoods for the majority of smallholder farmers. Within the Ethiopian food production, *teff* plays an essential role. It accounts for the largest share of cereal area under cultivation. About 6.62 million farmers grow the crop (Worku *et al.*, 2014) that occupies 28.7% about 2.9 million ha of cultivated land covered by cereals and is second only to maize in terms of volume of production (CSA, 2016). It is being produced by 48% of Ethiopian farmers (Worku *et al.*, 2014) and regarding the fact that it is a

very labor intensive crop (Setotaw, 2013). However, given the relatively low yields of *teff*; the total national production of *teff* was 5.1 million ton lower than maize which was 9.5 million ton (CSA, 2016). One of the presumed reason is that the prevailing agronomic practices restraining its productivity. Field demonstrations of row planting of *teff* showed that through planting seeds in rows the incidence of lodging is reduced and yields increase on average by 70% compared to the national average (Tareke *et al.*, 2011). Improved varieties of *teff* also produced a grain yield of 17-22 qt/ha on research fields and well managed large farms (Anteneh *et al.*, 2014). Consequently, these new production technologies are being promoted on a large scale to Ethiopian farmers (Bekabil *et al.*, 2011).

In Ethiopia, *Teff* production is a source of employment and livelihood for an estimated 25-30 million people. Further, *teff* is the most commercialized crop with approximately 36% of the total produced being marketed (Minten *et al.*, 2013). According to CSA (2013) as commercial surplus data indicates *teff* value was estimated to be 464 million USD on quarter lower than coffee (599 million USD), Ethiopia's most important export product. Moreover, the commercial surplus of *teff* is equivalent to the commercial surplus of the three other cereals (sorghum, maize and wheat) combined in the country. However, *teff* is the most expensive grain in Ethiopia since it requires labor intensive land preparation, weeding, harvesting and processing operations, while producing the lowest yield per hectare of all cereal crops (USAID, 2012).

Teff is relatively resistant to extreme weather conditions, as it can grow under both drought and waterlogged conditions better than other cereals (Minten *et al.*, 2013). Combined with its low vulnerability to pest and diseases, as compared to other cereals, it is considered as a reliable and low risk crop (Bekabil *et al.*, 2011). It can also be stored easily under local storage conditions for many years without being seriously damaged by common storage insect pests (Demeke and Di Marcantonio, 2013).

In most parts of Ethiopia, *teff* is usually sown during the main summer rainy season between July and August, while harvesting is done in most cases from November to February. Seeds are broadcasted on a well ploughed soil and lightly covered with soil until germination (Kebebew *et al.*, 2011). The sowing period of the crop is different from location to location on which wet sowing is preferred to avoid false start to improve seedling establishment (Araya *et al.*, 2010). The duration of *teff* growing period ranges from 80 to 85 days. Farmers typically broadcast seeds

in a scattered way by hand at high seed rates. This hampers *teff* yields since uneven distribution of the seeds makes weeding difficult and increased competition with weeds (Tareke *et al.*, 2011). Technologies such as row planting and transplanting, where the seed rate is reduced and more space between seedlings is given, are assumed to be superior to traditional broadcasting because they allow for weeding and diminish competition between seedlings (Bekabil *et al.*, 2011).

Teff has a vital role for growth yet it has been given little attention in research and development. It is still competitive to other cereals and is increasing in acreage. Moreover, it has remained an economically indispensable crop to Ethiopian farmers for several reasons namely: generation of household income, fulfilling concerns of nutritional needs, the price for its grain and straw are higher than other major cereals and its grain can be stored for a long period of time without being attacked by weevils. There is a potential to boost agricultural output like *teff* production by improving the efficiency of farmers through promoting new production innovation and technologies (CSA, 2013).

In Ethiopia, *teff* is mainly grown in Amhara and Oromia, with smaller quantities in the Tigray and SNNP regions (CSA, 2013). It is the most important crop in Amhara region, being the leading crop in terms of area coverage. It occupies 1.1 million ha of cultivated land cover by cereals (CSA, 2016). In Kobo district, *teff* has a vital role of achieving food security. The crop is one of the important traditional food crops in the area. It is also a multiuse crop, being utilized in different forms where the grain is mainly used for making *Injera* and local alcoholic drinks, called *Tela* and *Arekie*. In the district, a concerted effort was being executed to deliver improved agricultural inputs and technologies to the farming community through research-extension program to improve *teff* productivity. In this regard, three improved varieties were distributed to farmers by OKARD in collaboration with SARC and other NGO's. These varieties are *Quncho*, *Boset* and *Zobel* (SARC, 2015).

2.4. *Teff* Consumption in Ethiopia

Teff is a staple food crop for most households in rural and urban areas in Ethiopia. It is primarily grown to prepare *Injera*, bread, and some native alcoholic drinks (MoA, 2010). It is more eagerly eaten by urban households than by rural households. Guush *et al.* (2011) based on national household consumption data, found that urban consumption of *teff* per capita being as high as

61 kg per year. This compares to 20 kg per capita per year for rural areas. The author further illustrated income elasticity for *teff* of 1.10 in urban areas and that of rural areas of 1.20. In urban areas, the share of per capita *teff* consumption in total food expenditure is 23%, while in rural area this is only 6%. Hence, *Teff* is an economically better quality good and is relatively more consumed by the rich than by the poor. The lower consumption by the poor is also partly due to the high prices of *teff* which is typically twice as high as the cheapest cereal that was maize (Minten *et al.*, 2012).

In addition, *teff* is gluten free, rich in phosphorous, copper, aluminum and thiamine and is considered as better source of protein, amino acids and carbohydrates. The flour of the crop is a desirable ingredient in health products particularly for celiac disease patients. *Teff* can replace gluten-containing cereals in products such as pasta, bread, beer, cookies and pancakes. It is also higher in calcium, iron and zinc content than maize, wheat, rice and other cereals which makes it a preferable crop in Ethiopia (Kaleab, 2014).

2.5. Overview of Agricultural Technologies Adoption in Ethiopia

In Ethiopia, adoption of improved agricultural technologies has been a long-term concern of agricultural experts, policy makers, agricultural researchers, and many others linked to the sector. However, evidence indicates that adoption rate of modern agricultural technologies in the country is very low. Empirical studies on adoption of agricultural technologies are limited in geographical coverage. It is pertinent to undertake area-specific studies to assess the status of adoption and identify constraints that hamper further adoption of technologies (Admassie and Ayele, 2004).

The contribution of new agricultural technologies on household food security, income and commercialization can be realized when the use of the new technology is widely adopted. The technologies can be improved agricultural practices and associated inputs such as, improved varieties and fertilizer, management regimes such as soil fertility management, irrigation and water management. The new agricultural technology that enhances sustainable production and productivity is therefore critical for sustainable food security and income (Solomon *et al.*, 2011; Berihun *et al.*, 2014). However, the adoption pattern of these improved technologies has remained uneven particularly among the poor smallholder farmers living in the drought prone

areas of Ethiopia. Moreover, the speed of adoption of these technologies is rather found to be slow and irregular (Yitayal and Adam, 2015).

For many years, the government of Ethiopia working with extension program diffuses agricultural technologies to improve smallholders' crop productivity and farmer's income from surplus crop production. Paradoxically, different studies indicate that farmer's use of main agricultural inputs such as HYVs is less than 5%. The low adoption rate and use can be partly explained by limited access to input credit (Alemayehu *et al.*, 2013; CSA, 2013). Thus, there are initiatives by governmental and non-governmental organizations among the rural households to participate in different association such as agricultural cooperatives, farmer's group, savings and microcredit cooperative, other local groups. It is expected that farmers sharing and access information about new agricultural practices, HYVs, inputs and output price information. Hence, learning from others can play an important role in the adoption of new agricultural inputs in rural areas. Either in a social or economic network, learning externality could increase adoption of new agricultural technologies and encourage farmers' participation in improved agricultural practices (ATA, 2014).

The adoption of improved seed varieties developed as a result of modern breeding practices in Ethiopia has raised production. However low uptake of improved seed has been attributed to supply being less than demand resulting in inconsistent availability which may continue to be the main constraint for widespread adoption of improved varieties (Tesfaye, 2013).

Ethiopia's low productivity of the agricultural sector together with the rapid population growth relative to food production have forced the nation to be recipient of food aid and importer of commercial food grain (Belay, 2004). Hence, it is vital that agricultural production as well as productivity have to be increased at a proportionate rate through adoption of new technologies. But, as stated by Byerlee *et al.* (2007) the opportunity to increase production through area expansion is limited practically in the Ethiopian highlands. As a result, WB (2008) suggests that yield could be increased through more intensive use of improved technologies such as fertilizer and HYVs and the farmers need to adopt these new technologies so as increase production and productivity.

2.6. Theoretical Perspectives of Adoption

The concern of agricultural technology adoption by smallholder farmers is one of the development focuses in low income countries. This is mainly due to its contribution to improve agricultural production and productivity, income and food security of farm households. Hence, exploring the drivers for agricultural technologies adoption of smallholder farmers is believed to be vital to speed up the uptake and diffusion of the practices. However, understanding adoption is still a challenge and drivers of adoption were poorly understood. This is both at farmers' level, which practices were adopted and which is not. But also looking at vertical scaling, adoption takes place in the more institutional setting. Adoption accelerates to utmost when about half of the individuals in the system have adopted (Blazy *et al.*, 2010).

Households' level of adoption considers the decision made by the household head to comprise new or improved variety in usual farming practice. The decision made to adopt or otherwise depend on different factors. Farmers' decision to adopt improved agricultural technologies is assumed to be the product of a complex preference comparison made by a farm household. To adopt or not to adopt a technology or innovations is often a discrete choice (Guerre and Moon, 2006). These innovations consists of new ideas, methods, practices or techniques that provide the means of achieving sustained increase in farm productivities and income. The innovation may not be new to people in general but, if individual has not yet accepted it, to that person it is an innovation (Ray, 2001).

In wide ranging, farmer adoption decision of a given cultivar is usually a process, which passes through several stages. The first step is for the farmers to get to know the variety. Upon an initial assessment of the expected returns from the technology, the farmer may then decide to try out the technology. Depending on the performance of the technology, the evaluation by the farmer may take several growing seasons. If the technology is found attractive in terms of either increased profitability or reduced risk for risk-averse farmers, and if socioeconomic constraints do not limit the decision process, the farmer will decide to switch from the old to the new technology. Otherwise, the farmer will decide to reject the technology (Bekele *et al.*, 2007).

2.7. Analytical Framework for Adoption of Agricultural Technologies

Farmers' adoption decision behavior in a given period of time and space can be analyzed by using different models. Some of analytical models which are commonly used in adoption studies are qualitative choice models including linear probability function, ordered probit and logistic distribution. Multiple regression and discriminate analyses are less frequently used. These tools are often used independently or sometimes in combination with others (Mignouna *et al.*, 2011).

It is assumed that farmers' decisions in a given period of time and space are derived from maximization of expected utility or expected profit subject to resources constraints. Therefore, adoption depends on farmers' discrete choice of a new technology from a mix including the traditional technology and a set of components of the new technology (Feder *et al.*, 1985). To answer the question of what determines whether a particular technology is adopted or not and intensity of adoption, most of adoption of agricultural innovations studies used static rather than dynamic models. A static model refers to farmers' decisions to adopt an improved technology at a specific place and a specific period of time. This model attempts to answer the question of what determines whether a particular technology is adopted or not and what determines the pattern of adoption at a particular point in time (Ghadim and Pannell, 1999). One limitation of the static model is that it does not account for time in the adoption process or for the farmers' ability to learn to improve their technical efficiency in growing of the crop (Hailu, 2008). Whereas dynamic adoption models allow for changes in farmers' adoption decisions as farmers gain skills in growing the improved seed from year to year. In a dynamic model, at the beginning of each period the type of technology the farmer uses in that period, his allocation of land to different crops, and use of other variables are determined. This model used in few studies to explain adoption decisions (Ghadim and Pannell, 1999).

Discrete choice models are static adoption models and are widely been used in estimating models that involve discrete economic decision making processes (Guerre and Moon, 2006). The two commonly used discrete choice models in the adoption studies are the probit and logit models. The results from the two models are very similar since the normal and logistic distributions from which the models are derived are very similar except for the fact that the

logistic distribution has slightly fatter tails (Gujarati and Porter, 2010). The dependent variable which is normally used with these models is dichotomous in nature, taking the values 1 or 0, a qualitative variable which is incorporated into the regression model as dummy variable. In this case the value 1 indicates a farmer who adopts the improved varieties while the value 0 indicates the farmer who does not adopt. However these techniques do not separate out the influence of other variables and do not measure the intensity of adoption (Feder *et al.*, 1985).

The other alternative static adoption models used to analyze quantitative adoption decisions when information on the intensity of adoption is available are Tobit, Heckman and double-hurdle models (Feder *et al.*, 1985). The double hurdle model and Tobit model can alternatively use to identify factors which affect adoption and the intensity of adoption (Mignouna *et al.*, 2011). However, double-hurdle model is preferred to Tobit model because Tobit model is statistically restrictive as it assumes that the same set of variables determine both the equation probability of non-zero adoption and intensity use level. While, double-hurdle model is applied in such a way that, both hurdles (the decision for adoption and intensity of adoption) have equations associated with them, incorporating the effects of farmer's characteristics and circumstances. Such explanatory variables may appear in both equations or in either of one and most importantly, a variable appearing in both equations may have opposite effects in the two equations (Cragg, 1971). Heckman model is also another restrictive type of the double-hurdle model available because it assumes that none of the zero's for the non-adopters are generated by the adoption decisions (that is; first hurdle dominance) so that standard Tobit censoring is irrelevant (Jones, 1989).

There are different adoption models to be used for the adoption analysis based on the objective need to meet in the specific study. This study used double-hurdle model to see the relationship between dependent variable and the explanatory variables included in the study to meet the expected objective.

2.8. Empirical Studies on Agricultural Technologies Adoption

Various studies of technology adoption across different location revealed that a combination of socioeconomic, demographic, institutional and perception to technology attribute variables determine the adoption and intensity of use of the technologies. Therefore, this sub section

focuses on reviewing relevant studies on adoption around Ethiopia and outside Ethiopia that would give brief account of results and explanations behind the findings. The following are some of the results of previous studies.

Debelo (2015) assessed factors influencing adoption of quncho *teff* variety in Wayu Tuqa district of Ethiopia using logit model. Results of the study revealed that family labor availability, participation of farmers in agricultural trainings, education level of the household head, livestock holding (TLU), farmer's ability of meeting family food consumption and frequency of extension contact were enhancing the decision to adopt quncho *teff* while, age of household head, owning oxen and distance from household residence to market center were found to influence adoption of quncho *teff* negatively.

Similarly, Tsibuk (2015) analyzed the factors affecting adoption of quncho *teff* variety in Medebayzana woreda of Tigray region, Ethiopia using binary logit model. The result from the econometric regression binary logit model indicated that family labor availability, access to credit service, frequency of contacts with extension agents, participation in training, and mass media exposure are important variables which affect the adoption of quncho *teff* variety and had positive and significance influence on both the adoption decision and the extent of adoption. While, market distance and perception towards cost of inputs had negative and significance influence on both the adoption decision and the extent of adoption.

Mengistu and Bauer (2012) explored the determinants of adoption and labor intensity of stone-terraces in Eastern Highlands of Ethiopia. The study applied the double-hurdle model for analysis. The probit regression was used to measure the decision to adopt whilst the truncated regression was used to estimate the intensity of adoption. Results of the study indicated that the decision to adopt terraces and the decision on its intensity in terms of labor use were both positively and significantly affected by plot size, slope, and ownership of the parcel; training, age, and level of education of household head; proportion of land planted and involvement in off-farm activities.

Berihun *et al.* (2014) examined the underlying determinants of chemical fertilizer adoption by the rural households in Raya Azebo and Raya Alamata districts of Tigray region, Ethiopia. The probit regression result showed that sex of the household head, land ownership right security,

irrigation use, access to credit, contact with extension workers and off-farm participation were found to be positive in determining chemical fertilizer adoption decision. Besides, plot distance from the homestead, distance to the nearest market and TLU were significant while influencing chemical fertilizer adoption decision negatively. In a nut shell, difficulty of accessing credit either formally and informally, feel of non-secured land ownership right and fear of the damaging effect of technologies for crops grown due to shortage of water were found to be determinants of technology adoption. Furthermore, gender, given female headed households were mainly chemical fertilizer non-adopters since they could not be exposed to new and updated agricultural information, great discrepancy have been seen and founded.

Yenealem *et al.* (2013) investigated gender disparities in adoption of improved maize varieties between male headed and female headed households using binary probit model. The results revealed that the adoption of improved maize variety was biased by gender, where FHHs adopt the improved varieties less. Number of livestock units, extension services and land size had a significant and positive influence on the adoption decision of improved maize varieties, whereas age and distance to input market had negative and significant influence on the adoption decision for MHHs. The author found that the new maize variety is more likely to be adopted by MHHs with large farms. Their finding also showed that younger MHHs are more likely to adopt a new technology such as use of improved maize.

Empirical studies on agricultural technology adoption in Nigeria by Ayinde *et al.* (2010) and Idrisa *et al.* (2012) analyzed adoption of improved maize seed and its effect on household food security using bivariate probit model. They suggest that factors such as socio-economic characteristics of farmers, access to credit or cash resources and information from extension and other media influenced adoption rate of new agricultural technology among farmers. Ghimire (2015) also explored the factors affecting adoption of improved rice varieties among rural farm households in central Nepal using probit model. The study reported that seed access, education, farm size, land type, extension service and perception on yield potential of new varieties were significant variables which influence the probability of adoption of improved rice varieties.

Rafael (2011) examined the underlying determinants of agricultural technology adoption in Mozambique by using binary logit model. The major finding can briefly summarized as access to credit, higher level of education, access to extension advisory service and members of

agricultural associations were more likely to enhance adoption of new agricultural technologies. In the same study conducted by Kudi *et al.* (2011) farming experience, farm size and farmers' awareness had a considerable influence on the rate of adoption of agricultural innovation.

In a related study, Solomon *et al.* (2011) analyzed in their paper agricultural technology adoption, seed access constraints and commercialization and estimates the causal effect of adopting improved chickpea technologies on smallholder farmers' integration into output market in rural Ethiopia using double-hurdle model. Results of double-hurdle model confirmed that the level of adoption of improved chickpea varieties was strongly related to a range of household wealth indicator variables. Those households with more family labor force, livestock and land were considerably more likely to allocate extra land for the improved chickpea varieties. Ownership of these assets seems to ease the access of households to improved seed, some of which may be due to its potential effect on accessing credit. Livestock ownership also help farmers spread some of the risks they face.

Holden and Lunduka (2012) investigated the probabilities of fertilizer and manure use with panel probit and bivariate probit models and the intensities of input use with panel Tobit models in Malawi. They found that households with more livestock endowment and off/non-farm income were applying significantly more fertilizer on their plots, showing the importance of wealth for accessing fertilizer. Hence, households with more number of household's asset such as livestock asset were more likely to adopt fertilizer than with small number of livestock. The author also found age as an important factor which influenced the probability of adoption of new technologies negatively because it is said to be a primary latent characteristic in adoption decisions.

Bayissa (2014) use double-hurdle model to estimate the improved *teff* planting decision and intensity use of households in Diga district of East Wollega Zone. Results of double-hurdle model confirmed that both adoption and intensity use of improved *teff* were positively and significantly influenced by sex of the household head, farming experience, participation on crop production training, educational level, yield superiority and maturity period of new varieties. While, the author found that distance to the nearest market place had negative and significance influence on the adoption and intensity use of improved *teff* varieties.

An empirical study by Ermias (2013) also analyzes the adoption of improved sorghum varieties and farmers' varietal trait preference in Kobo district of Ethiopia using Tobit model. The author found that the farmer's adoption decision and intensity of use of improved sorghum varieties were positively and significantly influenced by irrigated farm size, tropical livestock unit, striga infested farm size, farmers' perception of yielding capacity and taste preference for improved sorghum varieties while active labor ratio, distance from farmers training center to home, proportion of sorghum farm from the total cultivated land and farm size had negative and significant influence on both the probability and intensity of adopting improved sorghum varieties.

Kapalasa (2014) examined factors influencing farmers' adoption of improved soybean varieties in Malawi using double-hurdle model. Demographic, socio-economic and Institutional factors such as age, access to extension services and distance to the nearest market of the household significantly influenced farmers' decision to adopt and intensity use of improved soybean varieties. The author also founds that farm level characteristics such as farm size and variety specific characteristics like earliness to maturity, higher yielding and pleasant taste were significant attributes that influence a farmer to adopt improved soybean variety. In a related study, Alemitu (2011) explored the factors affecting adoption of improved haricot bean production package using Tobit model. Results of the model indicated that the probability of adoption of improved haricot bean production package was positively and significantly affected by participation on demonstration, sex of household head, participation in field day and access to credit of improved haricot bean varieties seed in kind.

2.9. Conceptual Framework of the Study

Agricultural technology adoption and diffusion patterns often vary from location to location. The variations in adoption patterns proceed from the presence of disparity in agro-ecology, institutional and social factors. Moreover, farmers' adoption behavior, especially in low-income countries, is influenced by a complex set of farmer's socio-economic, demographic, institutional and environmental factors (Njane, 2007). Adoption rates were also noted to vary between different group of farmers due to differences in access to resources (land, labor, and capital) and information as well as differences in farmers' perceptions of risks and profits associated with

new technology. Practical experiences and observations of the reality have shown that, one factor may enhance households' adoption decisions of one technology in one specific area for certain period of time while it may create hindrance for other locations (Tesfaye *et al.*, 2001). Due to these reasons, it is difficult to develop a one and unified adoption model in technology adoption process for all specific locations.

The conceptual framework is a visual or written product that explains either graphically or in narrative form, the main things to be studied. The conceptual framework of this study is shown in Figure 1 below, which represents how various factors influence the probability of adoption and intensity use of improved *teff* varieties. The framework starts with identification of the driving factors for adopting improved *teff* varieties. From the extensive reviews, the factors can be grouped into demographic, socio-economic, institutional and psychological. Adoption of improved *teff* varieties is expected to have a considerable advantage in terms of increase in *teff* productivity and hence increased output. Then an increased output is expected to improve the welfare of *teff* producers. Improved welfare of farmers then provides a feedback effect in the form of enhancing their ability to participate in improved *teff* cultivation.

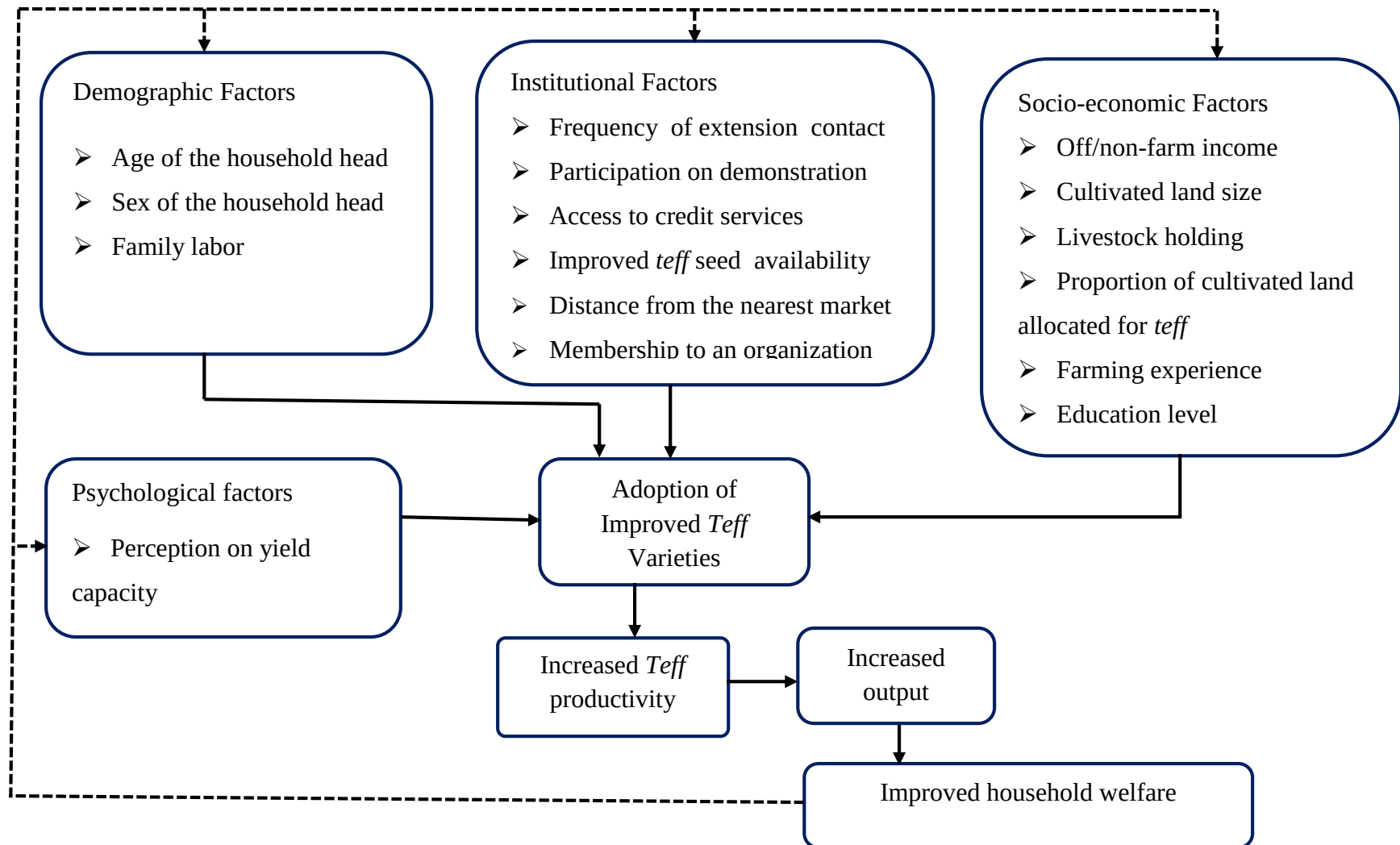


Figure 1. Conceptual framework of the study

Source: Own compilation based on literature

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location

The study was conducted at Kobo district, Northeastern escarpment of Amhara Region. The district is one of the eight rural districts in North Wollo Zone and lies about 54 Km North of Woldia town. The district town, Kobo is located on the Addis Ababa-Adigrat highway, 203 kilometers south of Mekele. Kobo is bordered on the south by the Logiya River which separates it from Habru and Guba Lafto, on the west by Gidan, on the north by Tigray Region, and on the east by the Afar Region. The landscape of this district is characterized by a broad fertile plain which is separated from the lowlands of the Afar Region by the Zobil Mountains, which are over 2000 m.a.s.l. In general, the altitude of Kobo ranges from 1100 m.a.s.l. on the plains to slightly more than 3000 m.a.s.l. along the border with Gidan (CSA, 2011; OKARD, 2015).

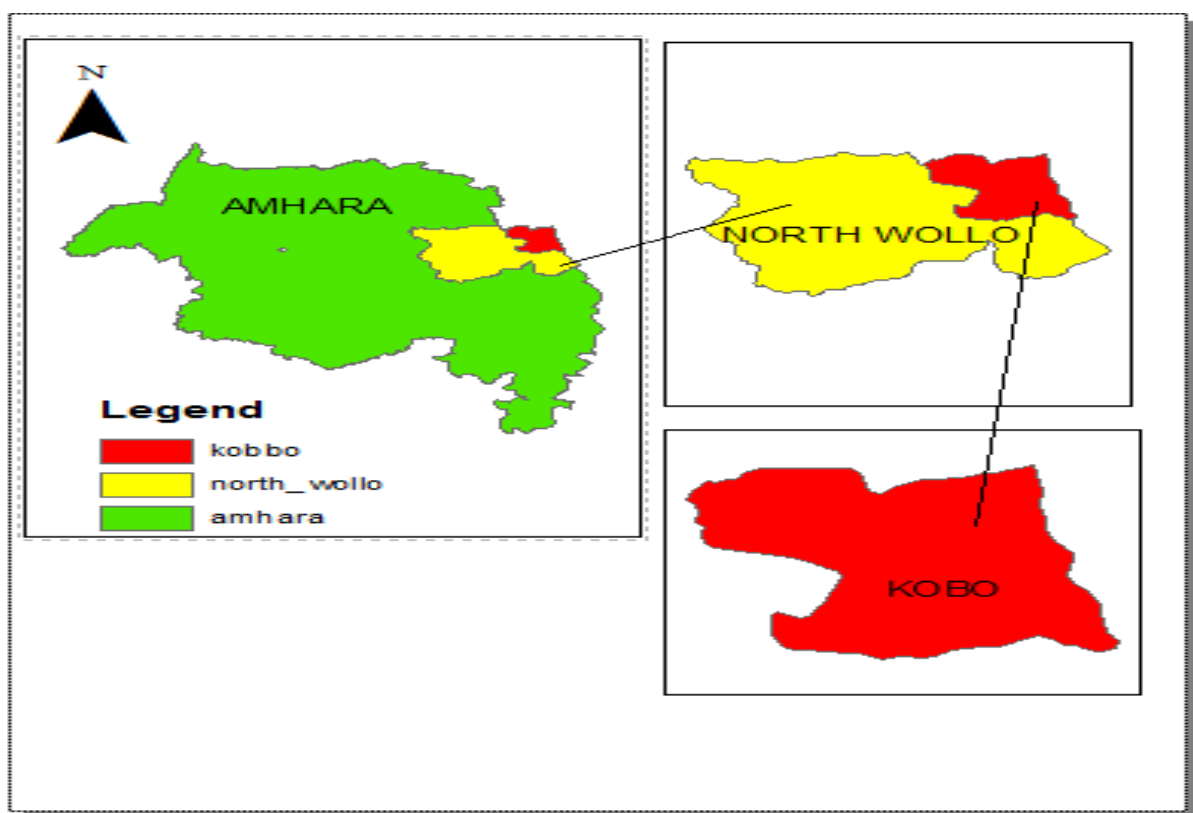


Figure 2. Location of the study area (Kobo District)

3.1.2. Climatic and Topography Features

Agriculture and Rural development office of the district reported that the topography of the area to be categorized as 65% plain, 15% rugged and the remaining 20% is mountainous. The agro-climatic feature of the district is tropical as 7.9%, 37.2% and 54.9% are *Dega*, *Weyina dega* and *Kola* respectively. Rainfall distribution over the area is characterized by erratic, short rainy season (*Belg*) and the long rainy season (*Meher*) that occurs in February-April and July-October respectively with a short dry spell (May-June). According to meteorological data from SARC (2015) the mean annual rainfall ranges between 500-800 mm while the temperature varies from a minimum of 19°C to a maximum of 33°C annually.

3.1.3. Population and Area Coverage

In Kobo district, there are 34 rural and 6 urban *Kebele* administrations. The urban *Kebele* administrations are located in Kobbo, Robit and Gobiye towns. According to CSA (2012), the total human population in Kobo district was estimated to be 239,504, an increase of 11.2% over the census, of whom 120,383 were males and 119,121 were females. The majority (82.88%) of the inhabitants practiced Ethiopian Orthodox Christianity, while 16.5% of the population are Muslim. The district has a total area of 2001.57 square kilometer. Kobo has a population density of 119.7 people per square kilometer, which is less than the Zone average of 132.3 persons per square kilometer. A total of 54,466 households were counted in this district, resulting in an average of 4.08 persons to a household (CSA, 2011; OKARD, 2015).

3.1.4. Agricultural Production

The agricultural practice in Kobo is mainly characterized by mixed farming system of which the crop sub-system dominates over livestock rearing. With regard to land use pattern of the district, cultivable land comprises the highest (29%) followed by 26.5% of degraded land. Kobo district shares 43.74% of the total 47,292.7 ha of irrigable land of North Wollo. Nearly 66.5% of the population in Kobo is engaged in mixed farming whereas 27% and 2% of the population depend only on crop and livestock production respectively (OKARD, 2015).

Crop production sub system in the district is both rain fed and irrigated. The rain fed crop production is dominated by cereals such as sorghum and *teff* whereas the irrigation crop farming

is dominated by vegetables and cereals again. Improved *teff* varieties cultivated in the district are *Quncho*, *Boset* and *Zobel*. Currently, *Quncho* and *Boset* are widely cultivated varieties by farmers. Other crops which grow in the district include barley, wheat, field pea and lentils. Chickpea is also grown when rainfall is late and not adequate to support the growth of other main crops. In addition to cereals, cultivation of the more commercial crops such as tomato, onion and pepper are undertaken during the dry season from March/April to June/July using irrigation water (OKARD, 2015).

3.2. Data Type, Sources and Methods of Data Collection

The study used data generated from both primary and secondary sources. Interview schedule was mainly used as a data collection tool. Accordingly, primary data were collected by interviewing smallholder farmers growing *teff* during the 2015/16 production season. Cross sectional data of 2015/16 production season was used. This contains both quantitative and qualitative data collected from selected households with semi-structured questionnaire. Before the administration of the interview schedules, the respondents were informed about the objectives of the survey. The interview schedules were also first pre-tested using non-sample respondents before actual data collection and amendments were made accordingly. Data collection was made with local trained enumerators. These local enumerators were recruited and trained to administer the interview under close supervision of the researcher. During the personal interview, primary data on key demographic, institutional and socio-economic factors affecting adoption decision and intensity of adoption of improved *teff* varieties and the perceptions towards improved *teff* attributes were collected. While, secondary data were collected from books, journals and other published and unpublished documents, from district agricultural offices, websites and other related sources to supplement primary data.

3.3. Sampling Procedure and Sample Size

Multi-stage sampling procedure was employed to select representative sample households. In the first stage of sampling procedure, Kobo District from North Wollo Zone was selected purposively based on maximum cultivated land under *teff* and its higher *teff* production from North Wollo Zone. In the second stage, four *Kebeles* were selected randomly from 20 *teff* producing *Kebeles* of the district. Then, the farmers in each randomly selected *Kebeles* were

stratified into adopter and non-adopter categories giving the relative homogeneity of sample respondents' adoption status. Hence, in this study, those farmers cultivated any of improved *teff* varieties during 2015/16 production season are considered as adopters and those who did not cultivate any of improved *teff* varieties in the same year as non-adopters. Finally, from each stratum of the randomly selected *Kebeles*, 150 representative sample respondents were selected randomly using probability proportional to size sampling technique. Due to heterogeneity of the population (adopters and non-adopters) the sample size was determined using the formula developed by Kothari (2004).

The formula is:

$$n = \frac{z^2 pq}{e^2} = \frac{(1.96)^2 (0.26)(0.74)}{(0.07)^2} = 150 \quad (1)$$

Where, n is the sample size for the study which is 150, z is the selected critical value of desired confidence level which is 1.96; p is the estimation proportion of an attribute that is present in the population which is 0.26, q=1-p =0.74 and e is the precision level which is 0.07.

Table 1. Size of sample households in the sample *kebeles* selected for the study

<i>Kebeles</i>	Number of Households			Sample taken		
	Adopters	Non-adopters	Total HH's	Adopters	Non-adopters	Total
Aradom	1230	1480	2710	22	27	49
Abuare	784	926	1710	14	17	31
Kalim	1081	849	1930	20	16	36
Mendefera	855	1015	1870	16	18	34
Total	3950	4270	8220	72	78	150

Source: own survey result, 2016

3.4. Methods of Data Analysis

The study used both descriptive statistics and econometric model for analyzing the data.

3.4.1. Descriptive Analysis

Descriptive statistics such as mean, standard deviation, frequencies distribution and percentage were employed in order to have clear picture about the socio-economic, institutional and demographic characteristics of sample households. Chi-square test and independent sample t-

test were used to test the significance of variables associated with the adoption and intensity of adoption and to identify variables that vary significantly between adopters and non-adopters. These tests were also used to see the presence of systematic association between those who adopt and those who do not in terms of hypothesized variables.

3.4.2. Econometric Analysis

Different researchers used different models for analyzing the determinants of technology adoption. In principle, the decisions on whether to adopt and how much to adopt can be made jointly or separately (Berhanu and Swinton, 2003). Various adoption studies have used Tobit model to estimate adoption relationships with limited dependent variables. Tobit model is, however, statistically restrictive because it assumes that the same set of variables determine both the probability of adoption and intensity level. In this case, the appropriate approach is to use double-hurdle model. This model assumes farmers faced with two hurdles in any agricultural decision making processes (Cragg, 1971). In this study, double-hurdle model was used since it allows for the distinction between the determinants of improved *teff* variety adoption and the intensity of use of improved *teff* varieties through two separate stages. This model estimation procedure involves running a probit regression to identify factors affecting the decision to adopt using all sample households in the first stage and a truncated regression model on the participating households to analyze the intensity of adoption in the second stage.

According to Burke (2009) double-hurdle model is useful regression model because it allows a subset of the data to pile-up at some value without causing bias in estimating the determinants of the continuous dependent variable in the second stage; hence all the data can obtain in the remaining sample for the participants. Thus, in double-hurdle model, there are no restrictions regarding the elements of explanatory variables in each decision equations and may appear in both equations or in either of one. That means, it is possible to separately analyze the determinants of production adoption decision and the intensity of adoption decisions. Due to this separability, the estimates of adoption decisions can be obtained by a means of probit regression and the intensity of adoption decision can be analyzed by using a truncated regression (Teklewold *et al.*, 2006).

Model specification: Originally proposed by Cragg (1971) the double-hurdle model is a parametric generalization of the Tobit model, in which two separate stochastic processes determine the decision to adopt and the intensity of adoption of technology. The underlying assumption in the double-hurdle was that a farmer makes two decisions with regard to his willingness to grow improved *teff* varieties. The first decision was whether to allocate a positive amount of land to improved *teff* variety at all while the second decision was about the amount of land allocated. As already noted, the general form of Cragg's double-hurdle model that was used for this study is specified as follows.

The double-hurdle model:

$$D_i^* = W_i' \alpha + U_i \text{ (Adoption Decision Equation)} \quad (2)$$

$$D_i = 1, \text{ if } D_i^* > 0$$

$$D_i = 0, \text{ otherwise}$$

Where, D^* is the latent variable describing the household's decision of whether or not to adopt improved *teff* varieties that takes the value 1 if the household adopted and 0 otherwise, D_i is the observed variable which represents the household's adoption decision, W_i is a vector of explanatory variables influencing household's initial adoption decision, α is a vector of parameters to be estimated and U_i is the error term.

$$Y_i^* = X_i' \beta + V_i \text{ (Intensity Equation)} \quad (3)$$

$$Y_i = Y_i^* = X_i \beta + V_i \text{ if } Y_i^* > 0 \text{ and } D_i^* > 0$$

$$Y_i = 0, \text{ otherwise}$$

Where, Y_i^* is the latent variable describing the intensity of adoption of improved *teff* varieties. Y_i is the area of improved *teff* varieties cultivated in hectare signifying the intensity of adoption. X_i is vector of explanatory variables influencing how much the household use improved *teff* varieties, β is a vector of parameters to be estimated and V_i is the error term. If both decisions are made by the individual farmers independently, the error term are assumed to be independently and normal distributed as:

$$U_i \sim N(0, 1) \text{ and} \\ V_i \sim N(0, \delta^2)$$

Therefore, the log-likelihood from the Cragg type double-hurdle model is the sum of the log-likelihood from a probit and a truncated regression. More useful, is the fact that these two component pieces are entirely separable, such that the probit and truncated regression can be estimated separately. According to Cragg (1971) the log-likelihood function for the double-hurdle model is given by:

$$\text{Log } l = \sum_0 \ln \left(1 - \Phi \left(W_i' \alpha \left(\frac{X_i \beta}{\sigma} \right) \right) \right) + \sum_+ \ln \left(\Phi(W_i' \alpha) \frac{1}{\sigma} \phi \left(\frac{Y_i - X_i \beta}{\sigma} \right) \right) \quad (4)$$

Where, Φ and ϕ are standard normal cumulative distribution function and density function respectively. The first portion is the log-likelihood for a probit while the second portion is the log-likelihood for a truncated regression, with truncation at zero.

3.4.3. Test for Model Appropriateness: Double-hurdle versus Tobit model

A hypothesis test for the double-hurdle model against the Tobit model was made. The test can be done by estimating three regression models (Tobit, truncated and probit regression models) separately and then conducting a likelihood ratio test that compares the Tobit with the sum of the log-likelihood functions of the probit and truncated regression models. The LR statistic can be computed using the formula developed by Greene (2003) as:

$$\Gamma = -2[\ln L_T - (\ln L_P + \ln L_{TR})] \sim \chi_k^2 \quad (5)$$

Where, L_T = likelihood for the Tobit model; L_P = likelihood for the probit model; L_{TR} = likelihood for the truncated regression model and k is the number of independent variables in the equations.

The test hypothesis is written as: $H_0 : \lambda = \frac{\beta}{\sigma}$ and $H_1 : \lambda \neq \frac{\beta}{\sigma}$

The null hypothesis (H_0) that Tobit model is the best fit model will be rejected on a pre-specified significance level if $\Gamma > \chi_k^2$.

3.4.4. Test of Multicollinearity

Multicollinearity is a situation that arises where there is strong linear association among the explanatory variables included in the model (Maddalla, 1992). Prior to running the double-hurdle model, an assessment for an existence of multicollinearity was checked. Accordingly a separate test for continuous and dummy variables included in the model was undertaken using VIF and contingency coefficient procedures respectively. VIF test was used to detect the presence of multicollinearity problem among continuous dependent variables. According to Maddalla (1992), VIF can be computed by using the formula:

$$\text{VIF (xi)} = \frac{1}{1 - R_i^2} \quad (6)$$

Where, R_i^2 is the squared multiple correlation coefficient between x_i and the other explanatory variables. As a rule of thumb a VIF value of more than 10 indicates high correlation among explanatory variables, while a VIF value less than 10 indicates weak association among explanatory variables (Gujarati, 2009).

Similarly, the existence of association among discrete explanatory variables was tested using contingency coefficient method by using the formula shown below. A value of 0.75 or more indicates stronger associations while a value less than 0.75 indicates weak association among explanatory variables.

$$\text{C.C} = \sqrt{\frac{\chi^2}{n + \chi^2}} \quad (7)$$

Where: C.C = Contingency Coefficient, n = sample size, and χ^2 =Chi square value.

3.5. Working Hypothesis and Definitions of Variables

Dependent variables: In the analysis of this study, two models that are probit and truncated in particular under the general double-hurdle model were employed. The dependent variable of the probit model takes a dichotomous value depending on the farmers' decision either to adopt or not to adopt improved *teff* varieties. However, the truncated regression model would have a continuous value which is the intensity of use of improved *teff* varieties. In this case, it indicates

the area of improved *teff* cultivated in hectare. Adopters are farmers who use improved *teff* varieties while non-adopters are farmers who did not use improved *teff* varieties during 2015/16 production season.

Independent variables: The independent variables used in the analysis and their theoretical expectations about the sign and magnitude of these variables on the adoption decision of agricultural technologies more particularly improved *teff* varieties and the intensity of use of improved *teff* varieties are discussed below. These variables were chosen based on the available literature reviewed.

Sex of the household head: It is a dummy variable which takes a value of 1 if the household head is male and 0 otherwise. According to Adebisi and Okunola (2013) male headed households would have better opportunity to adopt and use more improved technology since they are exposed to new information and tend to be risk takers. Hence, sex of household head was hypothesized to positively affect adoption and intensity of use of improved *teff* varieties.

Age of the household head: It is a continuous variable and measured in number of years from birth. Age of the household head is an important factor that would help to explain adoption decisions and intensity of use of improved technologies. According to Teklewold *et al.* (2006) and Sulo (2012) it is assumed that as farmers' age increases the probability of adoption is expected to decrease because as the farmer's age increases, they become conservative and their ability to perform various farm operations diminishes. On the other hand, older farmers may have more experience and resource that would allow them for trying new technologies. Therefore, the coefficient for this variable was hypothesized to be positive/negative for adoption decision and intensity of adoption of improved *teff* varieties as well.

Education level of the household head: It is a categorical variable defined as the level of grades by the household heads. As stated in Rafael (2011) educated farmers are believed to acquire, analyze and evaluate information on different agricultural inputs and technologies. Hence, the higher their education level, the more likely the farmers to adopt improved technologies. Therefore, education level of the household head was expected to have positive relation with adoption decision and intensity of adoption of improved *teff* varieties.

Cultivated land size: This is a continuous variable measured in hectare. It is likely to influence households' decision to adopt or not to adopt new technologies. As stated by Abera (2013) those farmers with large cultivated land size could adopt and use more improved technologies mainly to increase productivity. On the other hand, those with small cultivated land size could not be in a position to adopt improved technologies. Because, those farmers with small cultivated land size may fear the risk associated if there is crop failure. Hence, the coefficient this variable was hypothesized as positive for both adoption decision and intensity of adoption.

Family labor: Family labor was measured in terms of adult equivalent with the availability of active and productive family member in the household. Availability of family labor is likely to influence the gross margin of the adoption of the technology. A household with larger number of workers per unit of land area is more likely to be in a position to try and continue using a potentially profitable innovation and it was expected to influence adoption positively. Hassen (2014) found positive relationship between family labor availability and adoption. Hence, this variable was hypothesized to have positive relationship with adoption and intensity of adoption of improved *teff* varieties.

Distance from the nearest market: This is a continuous variable measured in kilometers. The longer the distance of farmers' residence to the nearest market, the improbable will be to get inputs and to sell outputs at the right time when they need and the lower will be their adoption decision for improved technologies. The closer the market is to the residence, the more likely that the farmers will receive reliable market information and transaction cost will also decrease. As confirmed by Hassen *et al.* (2012) and Bayissa (2014) an increase in market distance between farmers' residence and the market center decreases the adoption and intensity of use of improved technologies. It was hypothesized to affect adoption and intensity of adoption negatively.

Access to credit: It is dummy variable; representing 1 if the household had credit access and 0 otherwise. Credit access reduces liquidity problems that household could face while intending to purchase agricultural inputs and hence paves the way for timely application of inputs thereby increase the overall productivity and farm income. Since farmers with access to credit are more capable in accumulating capital than their counterparts who do not have access, these farmers adopt more (Anik and Salam, 2015). Hence, this variable was hypothesized to have positive relationship with adoption and intensity of use of improved *teff* varieties.

Frequency of extension contact: It is a continuous variable representing number of days a household is visited by extension agents. Farmers' visited by extension agents are believed to be exposed for different, new, and updated information used to adopt. Frequency of contact with extension agents also increases the availability of information about improved technologies and affect positively and significantly adoption decision of farmers (Leake and Adam, 2015). Hence, both for adoption decision and intensity of adoption, number of days contacted with extension agents' was expected to have a positive sign.

Membership to an organization: It is a dummy variable; representing 1 if a household is a member of a certain farmers' organizations and 0 otherwise. Membership to an organization let farmers to access inputs easily with an affordable price that is pertinent to increase agricultural production and farmers can easily adopt improved technologies (Tewodaj *et al.*, 2009; Rafael, 2011; Aman and Tewodros, 2016). Due to this, membership to organizations was expected to have a positive relationship with adoption and intensity of use of improved *teff* varieties.

Livestock holding: It is a continuous variable measured in TLU; where those who possess a flock of TLU are expected to adopt improved *teff* varieties better than they have not. Livestock holding is an important indicator of wealth status for the farm community. It is an important source of cash, manure, draft power and food for the agricultural community. The presence of tropical livestock unit can solve the liquidity problem that farm households face while intending to purchase and adopt improved *teff* varieties (Debelo, 2015). Hence, livestock holding was hypothesized to positively affect adoption and intensity of use of improved *teff* varieties.

Off/non-farm income: It is treated as a continuous variable which represents the amount of income the farmers earned in the year other than on-farm activity. It is the amount of income (in ETB) generated from activities other than crops and livestock. These include petty trading, charcoal selling, firewood selling, remittance, selling beverage, handcraft and others. This is believed to be the one source of capital for purchasing agricultural inputs. According to Hassen *et al.* (2012) and Brkalem (2015) households with relatively higher off/non-farm income are expected to better adopt improved technologies. Hence, off/non-farm income was hypothesized to affect adoption and intensity of adoption of improved *teff* varieties positively.

Participation on demonstration: It is treated as a dummy variable taking 1, for farmers participated on demonstration and 0, otherwise. Respondents' participation on demonstration is important to persuade farmers by showing the practical applicability of the technology selected to be adopted. It helps to put new innovation in to practice in the form of trial with close supervision of extension agents and other technical experts (Alemitu, 2011; Kafle, 2011). It was measured in terms of participation of farmers on demonstration which was expected to positively influence both farmers' adoption decision and intensity of use of improved *teff* varieties.

Perceptions on yield capacity. It is a dummy variable taking 1 for perceiving superiority of improved varieties over the locals in terms of yield and 0, otherwise. Farmers' perceptions for various attributes of improved technologies are vital variables in explaining adoption decision. Bayissa (2014) reported that farmer's perception on yield capacity is positively related on the probability of adoption and intensity of use of improved *teff* varieties. Accordingly, better perception on yield capacity for improved *teff* varieties was hypothesized to affect adoption and intensity of adoption positively.

Proportion of cultivated land allocated for *teff*: It is a continuous variable which indicates the share of *teff* farm in the survey year from the total cultivated land. The more the share of *teff* area from the total cultivated land size, the more attention the farmers give to the crop and the more likely they adopt new varieties in higher extent. As stated by Yu and Nin-Pratt (2014), an increase in the share of the crops area increases adoption of improved technologies. Hence, the proportion of cultivated land allocated for *teff* production was hypothesized to positively influence the adoption and intensity of use of improved *teff* varieties.

Improved *teff* seed availability: is a dummy variable that takes 1 if improved *teff* seed is available and 0 otherwise. In order to make use of the technologies, farmers should be able to get seeds either in the formal or informal distribution systems. Ghimire (2015) showed that institutional variables such as seed availability significantly and positively affect the incidence of adoption improved technologies. Thus, improved seed availability was hypothesized to positively influence the adoption and intensity of use of improved *teff* varieties.

Farming experience of the household head: It is the number of consecutive years since the farmer has started farming on his farmland. It explains adoption and intensity of use of improved

technologies as it improves farmers' skill of information accessing and utilization behavior. Bayissa (2014) found that experience in farming is positively related with the adoption of new *teff* technologies. Thus, farmers with better farming experience were expected to adopt improved *teff* varieties with better degree.

Table 2. Hypothesized definition of dependent and independent variables used for analyses

Variables	Type	Measurement	Hypothesis
Dependent variables			
Adoption of improved <i>teff</i> varieties	Dummy	1= adopter, 0=non-adopter	
Area of improved <i>teff</i> cultivated	Continuous	Ha	
Independent variables			
Sex of the household head	Dummy	1 if the household is male; 0 otherwise	+
Age of the household head	Continuous	No of years	+/-
Education level of the household head	Categorical	0=illiterate, 1= read and write, 2= grade 1-8, 3= grade 9 and above	+
Cultivated land size	Continuous	Ha	+
Family labor	Continuous	Adult Equivalent	+
Distance from market	Continuous	Km	-
Access to credit	Dummy	1 if access to credit; 0 otherwise	+
Frequency of extension contact	Continuous	Number of days	+
Membership to an organization	Dummy	1 if member; 0 otherwise	+
Livestock holding	Continuous	Number of livestock in TLU	+
Off/non-farm income	Continuous	ETB	+
Perception on yield capacity	Dummy	1 if superior to local, 0 if not superior	+
Participation on demonstration	Dummy	1 if the household participates; 0 otherwise	+
Proportion of cultivated land allocated for <i>teff</i>	Continuous	Ratio of land covered by <i>teff</i> to total cultivated land	+
Improve seed availability	Dummy	1 if seed is available; 0 otherwise	+
Farming experience	Continuous	Farming experience in years	+

4. RESULT AND DISCUSSIONS

In this chapter overall findings of descriptive and econometric analysis and discussions are presented. It is divided into two sections. The first section provides descriptive analysis of both adopters and non-adopters. While, in the second section the econometric analysis results from double-hurdle model are presented and discussed.

4.1. Results of Descriptive Analysis

This section presents and discusses demographic, socioeconomic and institutional characteristics of sample respondents such as age, sex, family labor, level of education, cultivated land size, farming experience, livestock holding in TLU, membership to an organization, participation on demonstration, access to credit, frequency of extension contact, and the like. The rate and intensity of improved *teff* varieties adoption and perceptions toward improved *teff* varieties attributes were also discussed.

Descriptive statistics such as mean, standard deviations, frequencies, and percentages as well as the probability levels of all explanatory variables were used to analyze and interpret the data. While, inferential statistics, such as t-test for continuous and chi-square tests for dummy and categorical explanatory variables were used to examine data for differences and associations between adopters and non-adopters.

4.1.1. Rate and Intensity of Improved *Teff* Varieties Adoption by Sample Households

A lot of efforts have been made by the research system to generate improved *teff* varieties and as a result, several varieties have been released. Among the released varieties, *Quncho*, *Boset* and *Zobel* were introduced to the study area through MoA and distributed to the farming community by OKARD. In the study area, farmers are commonly cultivating these improved varieties. Table 3 summarizes adoption status and area covered by improved *teff* varieties of adopter sample households. The results indicated that, out of the total adopters, 27(37.5%) of them were practice *Quncho*, 33(45.8%) were used *Boset* and it was most widely adopted variety, and only 12(16.7%) of the adopters were users of *Zobel teff* variety. In this study, the adoption intensity measures the depth or extent of adoption expressed in terms of area of land allocated to improved *teff* varieties. The results are presented in Table 3, which summarizes average area

of land allocated for each type of improved *teff* varieties by sample households. An average of 0.35 ha of land was found to be allocated for improved *teff* varieties by adopter sample households. Out of which, on average 0.11, 0.17 and 0.07 ha of land was allocated to *Quncho*, *Boset* and *Zobel* respectively.

Table 3. Adoption status and area covered by improved *teff* varieties

Variety	Growers		Average area (ha)
	N	%	
<i>Quncho</i>	27	37.5	0.11
<i>Boset</i>	33	45.8	0.17
<i>Zobel</i>	12	16.7	0.07
All improved varieties	72	100	0.35

Source: own survey results, 2016

Rate of adoption is the percentage of sample farmers who have adopted improved *teff* varieties. As indicated in Table 4, a total of 150 sample respondents were included in the survey, out of which 72(48%) and 78(52%) were found to be adopters and non-adopters of improved *teff* varieties respectively. Accordingly, the rate of adoption of improved *teff* varieties by sample households in the study area was found to be 48%.

Table 4. Rate of improved *teff* varieties adoption by sample households

Adoption categories	Adopters		Non-adopters		Total	
	N	%	N	%	N	%
	72	48	78	52	150	100

Source: own survey results, 2016

4.1.2. Descriptive Statistics for Dummy Explanatory Variables

Distribution of respondents by sex: In this study, out of the total 150 sample households 134 (89.3%) were male-headed households and the rest 16 (10.7%) were female-headed households. The proportion of male-headed households was 93.1% for adopters and 85.9% for non-adopters. Whereas, the proportion of female-headed households of the adopters (6.9%) was less than the non-adopters which was 14.1% (Table 5).

Education level of household head: Education is assumed to increase farmer's ability to obtain, process and use information relevant to the adoption of improved crop varieties. As indicated in

Table 5, about 38% of sample households had no schooling years at all (illiterate), 33.3% were able to read and write, about 24% had at least primary education (grades 1-8) and 4.7% of sample households were at educational level of secondary school and above (grades 9 and above). Out of adopters 16.7% were illiterate, 31.9% were able to read and write, a considerable proportion of the adopters (41.7%) had primary education (grades 1-8) and the remaining 9.7% of the adopters went to secondary school and above (grades 9 and above). With regard to non-adopters about 57.7% were illiterate, 34.6% were able to read and write and the remaining 7.7% were attended their primary education (grades 1-8). The result of the study revealed that the percentage difference between adopters and non-adopters with respect to education level was statistically significant at 1% probability level.

Participation on demonstration: Participation on demonstration creates an opportunity to evaluate the technology for its suitability for the given location whether to adopt or not according to the performance of it to the given location. It helps farmers to put new technology in to practice in the form of trial with close supervision of extension agents and other technical experts. The survey result in Table 5 indicated that 61.3% of sample respondents were participated on demonstration and the remaining 38.7% were not participated. Out of the total sample respondents 84.7% of the adopters and 39.7% of non-adopters were participated on demonstration during the survey year. About 15.3% of the adopters and 60.3% of the non-adopters were not participated on demonstration trial on the same year. The percentage difference among adoption categories related to this variable was found to be statistically significant at 1% level of significance.

Improved *teff* seed availability: Availability of improved seed varieties induces farmers to use the recommended varieties. The result of this study showed that the majority of the total sample respondents (85.3%) had access to improved *teff* seed in the study area, while 14.7% of sample households had no access to seed. About 98.6% of the adopters and 73.1 % of the non-adopters reported that they had access to improved *teff* seeds from different sources. These sources can be revolving seed funds, woreda agricultural and rural development office, bought from market, given by friend or neighbors. The chi-square analysis result revealed that the difference between the two groups with respect to this variable was statistically significant at 1% probability level (Table 5).

Access to credit: Credit service is an important source of finance for the poor farmers to buy inputs for agricultural production and ultimately to adopt new technologies. As shown in Table 5, out of the total sample respondents, about 44% got credit service from the woreda credit service delivering institutions to run their agricultural production accordingly. On the other hand, about 56% of the total sample households were not credit recipients. Additionally, 54.2% of the adopter and 34.6% of non-adopter sample households had access to credit services during the survey year. The remaining 45.8% of adopters and 65.4% of non-adopters had not access to credit service. The chi-square analysis result revealed that the difference between the two groups with respect to this variable was found to be statistically significant at 5% probability level.

Membership to an organization: In the realm of agricultural development, the importance of social capital is perceived as the willingness and ability to work together. The survey result in Table 5 revealed that 78.7% sample households were members to organizations while 21.3% of sample respondents were not members to organizations. About 84.7% of the adopter and 73.1% of the non-adopter sample households were members to organizations like farmers' associations/cooperatives, *ikub* and *idir*, irrigation group and credit and saving. While, 15.3% of the adopter and 26.9% of the non-adopter sample respondents were not participated in those organizations. The chi-square analysis result of the study revealed that, the percentage difference among adoption categories was statistically significant at 10% probability level.

Perception on yield capacity: It is supposed that farmers' perception of future benefit and cost of a new specific technology influences their adoption decisions. Farmers were asked to give their opinion about the yield performance of improved *teff* varieties. As indicated Table 5, about 66.7% of the sample households reported that improved *teff* varieties give greater yield per hectare than local varieties while 33.3% of sample households reported that improved *teff* varieties do not give greater yield than local varieties. With regard to the adoption categories, 86.1% of the adopters and 48.7% of the non-adopters were responded that improved *teff* varieties were better than local *teff* varieties in terms of yield. Whereas, 13.9% of the adopters and 51.3% of the non-adopters reported that improved *teff* varieties are not better than local varieties. The chi-square analysis result revealed that the percentage difference in perception on yield difference among the adoption categories was statistically significant at 1% probability level.

Table 5. Descriptive statistics for dummy explanatory variables

Variables		Adopters		Non-adopters		Total		χ^2 -value
		N	%	N	%	N	%	
Sex of household head	Male	67	93.1	67	85.9	134	89.3	2.01
	Female	5	6.9	11	14.1	16	10.7	
Education level	Illiterate	12	16.7	45	57.7	57	38	42.25***
	Read and write	23	31.9	27	34.6	50	33.3	
	Grade (1-8)	30	41.7	6	7.7	36	24	
	Grade 9 and above	7	9.7	0	0	7	4.7	
Participation on demonstration	Yes	61	84.7	31	39.7	92	61.3	31.94***
	No	11	15.3	47	60.3	58	38.7	
Improved <i>teff</i> seed availability	Yes	71	98.6	57	73.1	128	85.3	19.50***
	No	1	1.4	21	26.9	22	14.7	
Access to credit	Yes	39	54.2	27	34.6	66	44	5.81**
	No	33	45.8	51	65.4	84	56	
Membership to an organization	Yes	61	84.7	57	73.1	118	78.7	3.03*
	No	11	15.3	21	26.9	32	21.3	
Perception on yield capacity	Yes	62	86.1	38	48.7	100	66.7	23.56***
	No	10	13.9	40	51.3	50	33.3	

***, **and * denote the level of significance at 1%, 5% and 10% respectively.

Source: own survey results, 2016

4.1.3. Descriptive Statistics for Continuous Explanatory Variables

Age of the household head: As indicated in Table 6, the mean age of sample respondents at the time of the survey was 43.41 years with standard deviation of 9.43. The age structure of the sample respondents showed that adopters were younger (average age of 41.93 years with standard deviation of 8.90) than the non-adopters (average age of 44.78 years with standard deviation of 9.80). The two groups were found to be significantly different in terms of age at 10% probability level.

Farming experience of the household heads: Farming experience of the farmer is likely to improve the farmers' skill at production. The survey result in Table 6 shows that the average farming experience of sample household heads was about 19.05 years with standard deviation of 8.98. From the entire sample household heads, the average farming experience of adopters

was 20 years with standard deviation of 8.40 whereas for non-adopters it was 18.18 years with standard deviation of 9.46.

Family labor: The availability of active working labor force in the household is considered as the number of individuals who resides in the household's house to perform production activities. In this study, the average family labor of sample households was about 2.39 in adult equivalent with standard deviation of 0.95. The average family labor of sample adopter and non-adopter households was 2.75 and 2.07 in adult equivalent with standard deviation of 0.96 and 0.83 respectively. Hence, the study showed that there was significant mean difference in family labor availability in adult equivalent among the adoption categories at 1% significant level (Table 6).

Off/non-farm income of sample households: The use of improved technologies is directly or indirectly related with the level of income of the users. This direct relation is most of the time due the better purchasing power of the higher income groups than low income groups which induces access to technologies available. As Table 6 depicts, the average off/non-farm income of sample households in per year was about 4543.6 ETB with standard deviation 9468.6. On average, off/non-farm income of adopters was about 5574.2 ETB with standard deviation 9895.3 while non-adopters had 3592.2 ETB with standard deviation 9016.2.

Cultivated land size: Crop production requires primarily the availability of suitable cultivated land. In this study, the average cultivated land size of sample households was found to be 0.89 ha with standard deviation of 0.34. The average cultivated land size for non-adopter group was 0.81 ha with standard deviation of 0.29 while for adopter was 0.99 ha with standard deviation of 0.36. Hence, the t-test result showed that the mean difference between adopter and non-adopter farmers with respect to cultivated land size was statistically significant at 1% probability level (Table 6).

Livestock holding in TLU: Livestock is the farmers' important source of income and draught power for crop cultivation and is one of the main cash sources to purchase production inputs. In the study area livestock production constitutes an important element of the farming system of the community. As indicated in Table 6, the average livestock holding of the sample households was 2.74 TLU with standard deviation of 1.63. Adopters were found to own more livestock than their counterparts. It was observed that adopters of improved *teff* varieties had livestock holding

of 3.43 TLU with standard deviation of 1.61 and non-adopters had 2.11 TLU with standard deviation of 1.40. This study indicated that, mean difference among adoption categories related to livestock holding was statistically significant at 1% probability level.

Frequency of extension contact: Extension service is important institutional service that is required to increase agricultural productivity through the adoption of new technologies. It enables farmers being aware of the benefit of new technologies. The survey results in Table 6 shows that, sample households average extension contact per year was 7.33 with standard deviation of 4.59. The adopter's average extension contact per year was 7.67 with standard deviation of 4.88 whereas for the non-adopters it was 7.03 with standard deviation of 4.33 during the same year.

Distance from the nearest market: As indicated in Table 6, the average distance of sample respondents' home from the nearest market place was found to be 10.26 km with standard deviation of 1.89. On average adopters were located about 9.39 km with standard deviation of 1.80 and non-adopters were about 11.05 km with standard deviation of 1.62 away from the nearest market place. The t-test result revealed that the mean difference of distance from market between adopters and non-adopters was found to be significant at 1% probability level.

Proportion of cultivated land allocated for *teff*: As shown in Table 6, on average the proportion of cultivated land allocated for *teff* plantation by sample households was 0.38 with standard deviation of 0.16. on average adopters were tend to allocate higher proportion of land (0.42 with standard deviation of 0.19) for this crop as compared to non-adopters which is 0.34 with standard deviation of 0.13. Hence, the difference in proportion of cultivated land allocated for *teff* production between adopters and non-adopters was statistically significant at 1% probability level.

Table 6. Descriptive statistics for continuous explanatory variables

Variables	Adopters		Non-adopters		Combined		t-value
	Mean	Std. Dev.	Mean	Std.Dev.	Mean	Std. Dev.	
Age of the household head	41.93	8.90	44.78	9.80	43.41	9.43	-1.86*
Farming experience	20.00	8.40	18.18	9.46	19.05	8.98	1.24
Family labor	2.75	0.96	2.07	0.84	2.39	0.95	4.61***
Off/non-farm income	5574.2	9895.2	3592.2	9016.1	4543.6	9468.6	1.28
Cultivated land size	0.99	0.36	0.81	0.29	0.89	0.34	3.59***
Livestock holding	3.43	1.61	2.11	1.40	2.74	1.64	5.34***
Frequency of extension contact	7.67	4.88	7.03	4.33	7.33	4.59	0.85
Distance from the nearest market	9.39	1.80	11.05	1.62	10.26	1.89	-5.89***
Proportion of cultivated land allocated for <i>teff</i>	0.42	0.19	0.34	0.13	0.38	0.16	3.05***

***and *represents the level of significance at 1% and 10% respectively.

Source: own survey results, 2016

4.1.4. Farmers' Perception on Improved *Teff* Variety Attributes

Farmers' perception on different characteristics of a given technology could determine the decision of adoption and intensity of use. The hypothesis was tested based on different *teff* varietal attribute preferences of sample households. These attributes include farmers' perception on yielding capacity, lodging, maturity period, pest and disease resistance capacity of improved varieties and drought resistance were assessed and summarized in Table 7. Out of the total sample respondents, about 66.7% of them perceived that improved *teff* varieties in general give higher grain yield than local varieties. Considerable proportion of adopters, about 86.1% perceived that improved varieties are superior in their yielding capacity as compared to local *teff* varieties. However, it was only 48.7% of the non-adopters that perceived improved varieties give higher yield than local varieties. Based on the chi-square test the difference in perception on yield between adopters and non-adopters was statistically significant at 1% probability level. Farmers' perception on lodging of improved *teff* varieties is also another comparison criteria that farmers use in the study area to value the importance of the variety at hand. Accordingly, from the sample households, 31.3% reported that they perceived improved *teff* varieties are

better than the local ones in terms of lodging tolerance. It was also found that 26.4% of adopters and 35.9% of non-adopters perceived that improved *teff* varieties are lodging tolerance than local varieties. Whereas a significant proportion of adopters (73.6%) and non-adopters (64.1%) responded that improved *teff* varieties are less lodging tolerant than local varieties. A chi-square test also showed significant difference among adoption categories at 10% probability level in terms of perception on lodging. About 64.7% of the sample respondents reported that improved *teff* varieties are early maturing than local varieties. However, 35.3% of sample respondents responded local varieties are early maturing than improved varieties. A considerable number of adopters (86.1%) appeared to perceive that improved *teff* varieties are early maturing in contrast to the fact that 44.9% of non-adopters perceived the same. Farmers in the area prefer planting of early maturing *teff* varieties which can potentially compensate the time lag. With regard to disease resistance, about 46.7% of the respondents perceived that improved *teff* varieties are not easily attacked by disease and pests. About 55.6% of the adopters and 38.5% of the non-adopters perceived that improved *teff* varieties are more disease resistant than local ones. Finally, respondents were asked about drought resistant capacity of improved *teff* varieties as compared to local varieties. Accordingly, 48.7% of sample respondents reported that, improved *teff* varieties being more drought resistant than local varieties of which 52.8% of the adopters and 44.9% of the non-adopters perceived that improved varieties are better than local varieties in terms of drought resistant. While 47.2% of the adopters and 55.1% of the non-adopters perceived that improved varieties are not resistant to extreme weather conditions than local varieties.

Table 7. Perception of sample respondents about improved *teff* variety attributes

Attributes		Adopters		Non-adopters		Total		χ^2 -value
		N	%	N	%	N	%	
Better yield	Yes	62	86.1	38	48.7	100	66.7	23.56***
	No	10	13.9	40	51.3	50	33.3	
Lodging resistant	Yes	19	26.4	28	35.9	47	31.3	2.272*
	No	53	73.6	50	64.1	103	68.7	
Mature early	Yes	62	86.1	35	44.9	97	64.7	0.213
	No	10	13.9	43	55.1	53	35.3	
Disease resistant	Yes	40	55.6	30	38.5	70	46.7	4.39
	No	32	44.4	48	61.5	80	53.3	
Drought resistant	Yes	38	52.8	35	44.9	73	48.7	0.937
	No	34	47.2	43	55.1	77	51.3	

***and *represents the level of significance at 1% and 10% respectively.

Source: own survey result, 2016

4.2. Econometric Model Results

In the descriptive analysis, descriptions of sample households' characteristics and their relation with adoption of improved *teff* varieties and perceptions toward improved variety attributes were thoroughly presented. In this section, results and discussions from an econometric model analyses were presented. Accordingly, double-hurdle model was used to analyze the influence of various demographic, socio-economic and institutional variables on adoption and intensity of use of improved *teff* varieties. In the first stage, a binary probit model was used to analyze the influence of explanatory variables on adoption decision of sample respondents. Whereas, in the second stage, truncated regression model was used to analyze the determinants of those explanatory variables on the intensity of use of improved *teff* varieties.

Prior to the estimation of the models parameters, the presence of multicollinearity problem among the independent variables was checked. For continuous variables VIF was used to check multicollinearity problem and for dummy variables contingency coefficient was used. As the rule of thumb VIF values less than 10 is said to be weak association among explanatory variables. Accordingly, the VIF values displayed in the Appendix Table 1 shows that all the continuous explanatory variables had no serious multicollinearity problem. Similarly, the values of contingency coefficient were also low as shown in Appendix Table 2 which is less than the rule of thumb of 0.75 implying that a weak degree of association among the variables considered. Therefore, based on the above tests all the hypothesized continuous and dummy explanatory variables were kept in the respective models for further analysis.

The test statistics of the double-hurdle versus the Tobit model indicated the rejection of Tobit model and acceptance of the double-hurdle model. The test result in Appendix Table 5 revealed that the calculated statistical value of likelihood ratio was 90.64 which was greater than the tabulated or critical value of $\chi^2 (16) = 32$ at 1% level of significance. This shows the existence of two separate decision making stages during the adoption process. This result provides an empirical result of farmers' independent decisions making regarding the adoption and intensity of use of improved *teff* varieties in the study area.

4.2.1. Determinants of Adoption of Improved *Teff* Varieties

This section presents maximum likelihood estimates of probit model to identify determinants of adoption of improved *teff* varieties. The dependent variable for the probit model is the adoption decision of sample households. A total of sixteen explanatory variables, of which seven dummy and nine continuous, were included in the model. The maximum likelihood estimate result of probit model are summarized in Table 8 below. Out of sixteen explanatory variables, nine variables were found to be significantly determined adoption of improved *teff* varieties. The significant variables were educational level of the household head, off/non-farm income, proportion of cultivated land allocated for *teff* production, livestock holding in TLU, frequency of extension contact, participation on demonstration, improved *teff* seed availability, distance from the nearest market and farmers' perception on yielding capacity. The results from the model indicate how a given variable affects the probability of adoption of improved *teff* varieties.

The likelihood ratio of chi-square result revealed that the overall fitness of the model was found to be significant at 1% probability level. According to Wooldridge (2002) the probit regression coefficient gives signs of the partial effects of each explanatory variable on the response probability of the dependent variable. Detail of significant variables from this model are discussed as follows.

Education level of the household head: Education level of household head was found to be positively and significantly influenced the probability of adoption of improved *teff* varieties at 1% level of significance. Keeping other variables constant, as compared to illiterate farmers the probability of adoption of improved *teff* varieties for literate farmers would increase by 35.3%. This implied that literate farmers are more likely to adopt improved *teff* varieties than those who are illiterate. This might be due to relatively literate farmers having more access to information, capable to interpret and analyze the information and become aware to new technology than illiterate farmers and this awareness enhances the adoption of new technologies. The result could also be due to literate farmers are more rational and analyze the benefits of the new technology. Lavison (2013), Bayissa (2014) and Leake and Adam (2015) reported that having education increases the probability of adoption of new agricultural technology by farmers.

Off/non-farm income: As the model result indicates, the variable off/non-farm income was positively and significantly influenced the likelihood of adoption of improved *teff* varieties at 5% significance level. Keeping all other variables constant, for each additional 1% increase in off/non-farm income the probability of adopting improved *teff* varieties increases by 4%. Hence, the result of this study revealed that farmers with relatively higher off/non-farm income are more likely to use improved *teff* varieties as compared to farmers with lower income. The reason might be off/non-farm income increases the income of the household and might increase the capacity to invest in technology adoption. It is also expected to provide farmers with liquid capital for purchasing inputs necessary for *teff* production. Hassen *et al.* (2012) and Brkalem (2015) also reported that off/non-farm income positively influenced the probability of adoption of improved technology.

Proportion of cultivated land allocated for *teff*: The model result showed a positive and significant relationship between proportion of cultivated land allocated for *teff* and probability of adoption of improved *teff* varieties at 5% level of significance. Other variables held constant, the marginal effect showed that an increase in proportion of cultivated land allocated for *teff* by 1% would result in 148.8% increase on the probability of adoption of improved *teff* varieties. This result implied that farmers who allocate relatively higher proportion of land for *teff* are more likely to adopt improved *teff* varieties than farmers who allocate relatively smaller proportion of land for *teff* production. The reason might be an increased risk taking behavior of farmers' with an increase proportion of *teff* area. Therefore, a crop failure in choosing improved varieties might be compensated by an increased proportion of the crop area. Consistent with this, Yu and Nin-Pratt (2014) and Sibanda *et al.* (2016) found that the higher the share of crop area the more likely to increase the use of improved technologies.

Livestock holding: The number of tropical livestock unit affected positively and significantly the probability of adoption of improved *teff* varieties at 5% probability level. Other variables held constant, as the number of livestock increase by one TLU, the probability of adoption of improved *teff* varieties increases by 13.4%. This result showed that those farmers with large number of TLUs are more likely to adopt improved *teff* varieties than those who own small number of livestock. The result could be explained as, better risk bearing behavior of those wealthy farmers with better livestock would enable them to try those newly adopted *teff*

varieties. In addition, livestock could be a source of income that can be used to purchase inputs such as improved seeds, fertilizer and chemicals. It also enhances the shock absorbing capacity of the households in case of crop failure. Previous empirical findings by Solomon *et al.* (2011), Samson *et al.* (2012), Debelo (2015) and Leake and Adam (2015) confirms this result. According to their study being owner of more livestock increases the probability of adoption of improved agricultural technologies.

Frequency of extension contact: As hypothesized, frequency of farmers extension contact with agricultural extension agents had a positive and significant effect on the probability of adoption of improved *teff* varieties at 5% level of significance. Other variables held constant, for each additional contact with agricultural extension agents the probability of adoption of improved *teff* varieties increases by 2.8%. The result indicated higher probability of farmers with more contact with extension agents in adopting than farmers with less contact. The possible justification for this is that frequent contacts create awareness and build the necessary knowledge for using the innovation and enhancing the exposure of farmers on the adoption practice of improved technologies. Previous studies by yaregal (2011), Kudi *et al.* (2011) and Idrisa *et al.* (2012) also argued that farmers with more information through frequent contacts with extension agents are more likely to adopt improved varieties.

Participation on demonstration: Households' participation on crop production demonstration positively and significantly influenced the probability of adoption of improved *teff* varieties at 5% significant level. Other variables held constant, participation on demonstration would result in 36.7% increase on the probability of adoption of improved *teff* varieties. The result in relation to this variable showed that farmers who have opportunity to attend demonstration of improved *teff* technology are more likely to use improved *teff* varieties than those farmers who have no similar opportunity. The reason might be participation on demonstration help farmers to create awareness and promote the understanding about merits of the available information by showing the practical applicability of the technology selected to be adopted. This result goes along with the previous studies for instance Alemitu (2011) and Kafle (2011) argued that participating on demonstration motivate and enable famers to adopt improve agricultural technologies.

Improved *teff* seed availability: Availability of improved *teff* seed was found to be positively and significantly influenced the probability of adoption of improved *teff* varieties at 5%

probability level. Other variables held constant, timely availability of improved *teff* seed brings about 52.5% increase in the probability of adoption of improved *teff* varieties. The result implied that those farmers who get improved seed are more likely to adopt improved *teff* variety than those who do not have access to improved seed. The possible explanation for this finding could be timely availability of seeds either in the local stores or in the market eases the households to purchase and cultivate new improved varieties in their fields. This is expected as farm households residing in remote areas hardly get reliable sources of improved seeds, magnifying the importance of the availability of seed in local area. The result is consistent with studies by Ghimire (2015) and Verkaart *et al.* (2016) who found that the higher the availability improved seeds the more the probability of adopting improved varieties.

Distance from the nearest market: As expected, distance from the nearest market was found to be negatively and significantly influenced the probability of adoption of improved *teff* varieties at 1% level of significance. Keeping other variables constant, an increase in distance from farmers' residence to market place by a kilometer would result in 14.6% reduction on the likelihood of adoption of improved *teff* varieties. The result implied that the longer the distance between farmers' residence and the market place, the lower will be the probability of adoption of improved *teff* varieties. The plausible explanation for this result might be farmers nearby the market centers had more access to production inputs, have higher probability of obtaining up-to-date market information and hence access more information about improved technology that could enable them to try new technologies than those farmers who are in distant location. The finding of this research is in line with Hassen (2014) and Debelo (2015). They found that an increase in distance from market center increases transaction costs related to the sale of farm output and acquisitions of critical input that would reduce farmers' incentives to engage in agricultural production activities using improve technologies.

Perception on yield capacity: Farmers' perception of better yielding character of improved *teff* varieties was significantly and positively affected the adoption decision of the farm households at 5% level of significance. Other variables held constant, a change in the perception of the farmer on the yield of improved variety to be higher than that of local variety (that is, a change from 0 to 1) brings 33.8% increase in the probability of adoption. The result of this study showed that if farmers perceive that new varieties are superior in terms of yield as compared to the local

varieties, they will more likely adopt and widely use them. The possible reason is that farmers' interest of maintaining and enhancing *teff* yield in the production year. Similarly, Ermias (2013), Bayissa (2014) and Kapalasa (2014) reported that the better perception on yield, the more adoption of improved varieties.

Table 8. Probit estimates of the factors affecting adoption of improved *teff* varieties

Variables	Coefficient	Std.Error	Marginal effect
Sex of the household head	-0.1249	0.6666	-0.0498
Age of the household head	0.0072	0.0281	0.0029
Educational level	0.8851***	0.2481	0.3527
Family labor	0.1336	0.2247	0.0532
Off/non-farm income	0.1005**	0.0422	0.0400
Farming experience	0.0082	0.0278	0.0032
Cultivated land size	-0.6307	0.7371	-0.2513
Proportion of <i>teff</i> cultivated land	3.7331**	1.8491	1.4875
Livestock holding	0.3352**	0.1606	0.1335
Frequency of extension contact	0.0705**	0.0349	0.0280
Participation on demonstration	0.9678**	0.4505	0.3673
Improved <i>teff</i> seed availability	1.7774**	0.8102	0.5254
Distance from the nearest market	-0.3674***	0.1103	-0.1464
Access to credit	0.4732	0.3697	0.1869
Membership to an organization	0.3758	0.5125	0.1472
Perception on yield capacity	0.8915**	0.4441	0.3380
_CONS	-4.6099***	1.7801	—
LR χ^2 (16)	131.22		
Prob> χ^2	0.000		
Log likelihood	-38.24		
Pseudo R^2	0.63		
Number of observations	150		

*** and ** represents the level of significance at 1% and 5% respectively.

Source: Model output

4.2.2. Factors Determining the Intensity of Adopting Improved *Teff* Varieties

This section focuses on factors determining the intensity of farmers *teff* production participation, conditional on decision to adopt improved varieties. Truncated regression model was used in this case, which is the second stage of the double-hurdle model. The dependent variable for this model was the intensity of use of improved *teff* varieties. In this case, it indicates the area of improved *teff* cultivated in hectare in 2015/16 production season. Out of sixteen explanatory variables, seven variables were found to be significantly affected the intensity of adoption of

improved *teff* varieties. The significant variables were sex of the household head, age of the household head, family labor, off/non-farm income, proportion of cultivated land allocated for *teff* production, frequency of extension contact and membership to an organization. The results of this model denote how a variable influences the level of usage, given that a decision is made to adopt the improved *teff* varieties. The wald ch-square result of the analysis revealed that the overall fitness of the model was found to be significant at 1% probability level. Detail of significant variables from this model are discussed as follows.

Sex of the household head: Sex of household heads was found to be positively and significantly influenced the intensity of use of improved *teff* varieties at 5% level of probability. Keeping all other variables constant, as compared to female headed households, the intensity of use of improved *teff* varieties for male headed household increased by 14.7%. The estimated coefficients for this dummy variable reveals the existence of different level of *teff* production participation based on sex of the household head. The result suggests that those male headed households are more likely to allocate larger amount of land to improved *teff* varieties than their counter parts, *ceteris paribus*. This could be attributed to various reasons, which could be the problem of economic position of female headed households, including shortage of labor, limited access to information on improved varieties and required production inputs due to social position. The result is consistent with the findings of Lavison (2013), Hassen, 2014 and Bayissa (2014) who showed that male headed households are more likely to allocate larger amount of land to improved *teff* varieties than female headed households.

Age of the household head: Age had negative and significant influence on the intensity of use of improved *teff* varieties at 5% probability level. Other variables held constant, as age of the household increases by a year, the intensity of use of improved *teff* varieties decreases by 0.5%. The result implied that older household heads are resistant and less likely to adopt improved varieties than young household heads. The possible justification is that as the household heads get old they might reduce trust towards new technologies adoption as new technologies need financial investments (seed, fertilizers, and labour) and intensive field managements. Hence, as age increases the intensity of use of improved *teff* varieties declines. The result in accordance with Teklewold *et al.* (2006), Samson *et al.* (2012) and Aman and Tewodros (2016) reported that younger farmers are more likely to adopt new technologies compared to older farmers.

Family labor: Family labor in adult equivalent was positively and significantly influenced the intensity of using improved *teff* varieties at 10% probability level. Keeping all other variables constant, a unit increase in family labor, increases the intensity of use of improved *teff* varieties by 2.6%. This result indicated that farmers with high labor force are more likely to allocate more hectares of land to improved *teff* varieties than those with low labor force. The possible reason for this finding is that improved varieties need improved practices and these practices are labor intensive and hence the household with relatively high labor force uses improved technologies on their farm plots more than others with low labor force. Moreover, *teff* production is a labor-intensive activity. Hence, a household with high working labor force would be in a position to manage the labor-intensive *teff* production activity. Previous studies by Solomon *et al.* (2011), Samson *et al.* (2012), Hassen (2014) and Leake and Adam (2015) also reported that the more family labour available the better intensity of adoption of agricultural technologies.

Off/non-farm income: Off/non-farm income positively and significantly influenced the intensity of using improved *teff* varieties at 1% level of significance. Other variables held constant, 1% increase in off/non-farm income increases the intensity of use of improved *teff* varieties by 0.9%. This result showed that households with relatively higher off/non-farm income are expected to allocate more hectares of land to improved *teff* varieties than their counterparts. The probable reason for this finding is that additional income earned through participation in off/non-farm activities improves farmers' financial capacity and might increase the ability to acquire improved seeds and associated inputs. This result goes along with the previous studies by Hassen *et al.* (2012), Berihun *et al.* (2014) and Brkalem (2015). In their studies, they found that an extra income obtained through participation in off/non-farm activity enhance the farmers ability to allocate more of their land to improved technologies.

Proportion of cultivated land allocated for *teff*: The estimated coefficient result of proportion of cultivated land allocated for *teff* was found to be positive, reflecting that, the variable was found to be positively and significantly influenced the intensity of using improved *teff* varieties at 5% level of significance. Other variables held constant, each 1% increase in proportion of cultivated land allocated for *teff* production would result in 23.4% increase in the intensity of use of the improved *teff* varieties. As stated in Yu and Nin-Pratt (2014) and Sibanda *et al.* (2016) farmers who allocate higher proportion of cultivated land for their crops are more likely to use

improved technologies extensively than those farmers with smaller proportion of cultivated land.

Frequency of extension contact: Frequency of extension contact was found to be positively and significantly influenced the intensity of adoption of improved *teff* varieties at 10% probability level. Keeping all other variables constant, the intensity of adopting improved *teff* varieties increases by 0.45% as for each additional contact with agricultural extension agents. The result implied that frequent contact with extension agents increases the availability of information about improved technologies and make farmers being aware of new technologies on how they can apply and hence increase the intensity of use of technologies. Similarly, Idrisa *et al.* (2012), Hassen *et al.* (2012) and Leake and Adam (2015) found that extension services enable farmers to get exposed and more familiar with new technologies and can stimulate them to allocate more of their land to improved technologies.

Membership to an organization: Intensity of use of improved *teff* varieties was positively and significantly influenced by membership of organizations at 1% level of significance. Keeping other variables constant, as compared to non-membership to organizations, being membership in organizations would increase in the intensity of use of improved *teff* varieties by 10.6%. Farmers' organization could served as a platform for accessing and dissemination of new information and improved technologies. Hence, the result of the study implied that farmers belonging to organizations have easy access to information, credit, labor and inputs such as, fertilizer, improved seeds and chemicals and are expected to allocate more hectares of land to improved varieties. The result is consistent with previous studies, for instance Tadesse (2008), Mekuria (2013) and Aman and Tewodros (2016) argued that farmers who participated in organizations were more likely to engage in social learning about new practices and technologies and hence raising the intensity of use of technologies.

Table 9. Truncated regression estimates for intensity of use of improved *teff* varieties

Variables	Coefficient	Std.Error
Sex of the house hold head	0.1468***	0.0543
Age of the household head	-0.0049**	0.0021
Education level	-0.0100	0.0145
Family labor	0.0263*	0.0139
Off/non-farm income	0.0090***	0.0028
Farming experience	-0.0028	0.0020
Cultivated land size	-0.0683	0.0566
Proportion of <i>teff</i> cultivated land	0.2335**	0.1026
Livestock holding	0.0041	0.0087
Frequency of extension contact	0.0045*	0.0025
Participation on demonstration	0.0389	0.0411
Improved <i>teff</i> seed availability	-0.0576	0.1060
Distance from the nearest market	0.0023	0.0070
Access to credit	0.0278	0.0248
Membership to an organization	0.1057***	0.0339
Perception on yield capacity	0.0057	0.0380
_CONS	0.1932	0.1534
Wald chi2 (16)	78.24	
Prob > chi2	0.000	
log likelihood	70.39	
Number of observations	72	

***, ** and * represents the level of significance at 1%, 5% and 10% respectively

Source: Model output

5. SUMMARY, CONCLUSIONS AND RECCOMENDATIONS

5.1. Summary and Conclusions

The use of improved variety is considered as the main important input for the achievement of increased agricultural productivity and food security status of farm households in Ethiopia. As part of this goal, there has been an increasing effort by the government technology scaling out programs to improve crop productivity primarily through agricultural intensification, involving an increased use of inputs, including seeds of improved crop varieties.

Teff is one of the cereal crops which plays a paramount role in achieving food security and enhancing income of households in most parts of Ethiopia and in particular in Wollo area. Furthermore, the crop is one of the most widely cultivated and consumed cereals in the area. Regarding its contribution, the research-extension program of the national agricultural research system has been disseminating several yield increasing improved *teff* varieties. However, the adoption and intensity of use of such improved varieties being extended by the research system has not been studied in the study area so as to identify the gaps and make an intervention.

Therefore, the study was initiated to identify factors that affect the probability of adoption and intensity of use of improved *teff* varieties in the study area. The general objective of this study was to identify the determinants of the probability of adoption and intensity of use of improved *teff* varieties in kobo district. The study employed cross-sectional data to analyze the effect of farmers' demographic, socio-economic, institutional and psychological factors on the probability and intensity of use of improved *teff* varieties.

For this study, Kobo district was selected purposively based on its higher *teff* production from North Wollo Zone. Then, four kebeles were selected using random sampling technique and stratified in to adopter and non-adopter categories. Finally, 150 sample households were selected using probability proportional to size sampling technique. Selected sample households were interviewed to generate data for the 2015/16 cropping season using a semi-structured questionnaire that encompasses questions related to demographic, institutional, and socio-economic and perception related variables. Moreover, secondary data obtained from various relevant sources were used in this study.

The study used both descriptive statistics and econometric model for data analyses. Results of descriptive analysis generally showed that adopter of improved *teff* varieties differ from their counterparts in various demographic, socio-economic and institutional related perspectives. Moreover, farmers' perception on yielding capacity and lodging tolerance of improved *teff* varieties, educational level, availability of improved *teff* seed varieties, livestock holding, participation on demonstration and distance from the nearest market were compared and showed variation between the two adoption groups. The result of this study showed that 48% of sample farmers have already adopted improved *teff* varieties showing a relatively low rate of adoption of the technology in the study area. Results of descriptive analysis also showed that, adopters were allocated an average 0.35 ha of land to improved *teff* varieties.

A double-hurdle model was employed to identify farmers' decision to adopt and the intensity of use of improved *teff* varieties. The choice of the model was based on the assumptions of independent adoption and intensity of use decisions and normally distributed error terms. The result shows that the use of improved *teff* varieties follows two independent decisions: the decision to adopt it and the decision concerning intensity of use. The result of a double-hurdle model shows that among sixteen explanatory variables used in the regression analysis, level of education, off/non-farm income, proportion of cultivated land allocated for *teff* production, frequency of extension contact, livestock holding, participation on demonstration, improved *teff* seed availability, and perception on yield were found positive and significant in the first hurdle (probit model) while distance from the nearest market had negative and significant effect. Whereas, in the second hurdle (truncated model), sex of household head, age of household head, off/non-farm income, family labor, proportion of cultivated land allocated for *teff*, frequency of extension contact and membership to an organization were found to be significantly influenced households intensity of use of improved *teff* varieties.

The finding of this study revealed that some of the variables under investigation affecting the probability of adoption decisions were not affecting the level of usage of improved *teff* varieties and vice versa. The result also confirmed the model assumptions of independent sets of variables can affect the probability of adoption decisions and the intensity of use decisions.

In general, the study concluded that adoption decision and intensity of use of improved *teff* varieties were driven by a host of institutional, demographic, psychological and socio-economic

factors. These factors play a crucial role in influencing the farmers' adoption decision and intensity of adoption. However in the study area, the performance of farmers in terms of use improved *teff* variety has not been to the expected levels. Hence, concerted efforts should be made to promote the use of improved agricultural technologies in *teff* farming.

5.2. Recommendations

Based on the empirical findings of the study, the following recommendations are suggested to be considered in the future intervention strategies which are aimed at promotion of improved *teff* varieties.

In the study area, education was found to be positively and significantly influencing likelihood of adoption of improved *teff* varieties. The diffusion of technology thus needed to be facilitated through educated farmers to be used as contact farmers so that they can use the available inputs more efficiently under the existing technology. Besides, the district office of education need to strengthen adult education programmes to change farmers' attitude and orientation towards new technologies.

Age of household head had negative and significant effect on the intensity of adoption of improved *teff* varieties. Therefore, stakeholders in the study area including the district offices of agriculture and agricultural experts need to arrange experience sharing and provision of short-term training programs so as to create awareness among older farmers.

Sex of the household head was positive and significant on the intensity of use of improved *teff* varieties suggesting that due attention should be provided for promoting and empowering females by addressing the resource and information constraints. Family labor was also an important factor which enhance the intensity of use of improved *teff* varieties. Therefore, policies and strategies should consider availability of labour force before introducing labour intensive technologies.

Number of extension contact was found to be positively and significantly influencing the adoption and intensity of use of improved *teff* varieties as it enhances ability to acquire and use information required for production. Therefore, strengthening extension service is needed to increase farmers' awareness about the benefits of using improved *teff* technologies including

improved *teff* varieties. Furthermore, concerted efforts need to be done by the district agricultural extension office to update the theoretical and practical knowledge of the extension personnel about newly developed improved agricultural technologies.

The study indicated that participation in demonstration had positive and significant influence on adoption and intensity of use of improved *teff* varieties. Therefore, policy makers and other development partners involved in agricultural development need to strengthen provision of more agricultural services like demonstrations of new technologies.

Improved seed availability had positive and significance influence on the probability of adoption of improved *teff* varieties. In the study area, thus, emphasis need to be given to increase adoption of improved *teff* varieties by making better access to improved seeds timely at affordable prices. Further, stakeholders including research institutions, NGOs, district office of agriculture and farmers' cooperatives prevailing in the seed systems need to support seed grower farmers' associations to ensure adequate supply of improved *teff* seeds at farmers' level.

Distance from the nearest market negatively and significantly affecting adoption of improved *teff* varieties. Hence, improving the existing market center in the study area through construction of whether roads and providing good transport facilities for farmers need to be given more attention to enhance the adoption of improved *teff* varieties.

Membership to an organization was found to be positively and significantly influencing the intensity of improved *teff* varieties adoption. Hence, in the study area, farmers' organization need to be strengthened to reinforce farmer-to-farmer knowledge sharing and much effort should go through to capacitate their human and financial resources by providing incentives so that they can be the center for agricultural technology transformation.

Perception on yield capacity was found to be positively and significantly influencing adoption of improved *teff* varieties. This suggests that due attention need to be given by researchers to improve the yield potential of existing and new varieties of *teff*. Number of livestock holding affected new *teff* varieties adoption positively. Hence, stakeholders in the study area including the district offices of agriculture and veterinary clinics need to strengthen the existing crop-livestock production system through providing improved veterinary services, better livestock feed and adopting high-yielding breeds.

6. REFERENCES

- Abera Abebe. 2013. Determinants of adoption of improved wheat varieties by smallholder farmers: The Case of Angacha Woreda, Kembata Tembaro Zone, SNNPR, Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- Adebiyi, S. and Okunlola, J.O. 2013. Factors affecting adoption of cocoa farm rehabilitation techniques in Oyo State of Nigeria. *World Journal of Agricultural Sciences*, 9(3):258-265.
- Admassie Assefa and Ayele Gezahegn. 2004. Adoption of improved technology in Ethiopia: Ethiopia Development Research Institute Report. Addis Ababa, Ethiopia.
- Alemayehu Taffes, Dorosh, P. and Sinafikeh Asrat. 2013. Crop Production in Ethiopia: Regional Patterns and Trends. International Food Policy Research Institute, ESSP II Working Paper, Ethiopia.
- Alemitu Mulugeta. 2011. Factors affecting adoption of improved haricot bean varieties and associated agronomic practice in Dale Woreda, Ethiopia. MSc Thesis, Hawassa University, Hawassa, Ethiopia.
- Aman Tufa and Tewodros Tefera. 2016. Determinants of improved barley adoption intensity in Malga District of Sidama Zone, Ethiopia. *International Journal of Agricultural Economics*, 1(3):78-83.
- Anderson, J.R. 2007. Agricultural advisory services. Background paper for the world development report 2006. World Bank, Washington, D.C., USA.
- Anik, A.R. and Salam, M.A. 2015. Determinants of adoption of improved onion variety in Bangladesh. *Journal of Agriculture and Environment for International Development*, 109 (1): 71-88.
- Anteneh Abewa, Birru Yitaferu, Yihenew Gebereselassie and Tadele Amare. 2014. The role of biochar on soil reclamation and yield of *teff* (*Eragrostis teff* [Zucc] Trotter) in North Western Ethiopia. *Journal of Agricultural Science*, 6(1):210-222.
- Araya, A. and Stroosnijder, L. 2010. Effects of tied ridges and mulch on barely (*Hordeum vulgare*) rainwater use efficiency and production in North Ethiopia. *Agricultural Water Management*, 97(6): 841-847.

- ATA (Agricultural Transformation Agency). 2012. Working Strategy for Strengthening Ethiopia's *Teff* Value Chain Vision, Systemic Challenges, and Prioritized Interventions. Addis Ababa, Ethiopia.
- ATA (Agricultural Transformation Agency). 2013. Results of 2012 New *Teff* Technologies Demonstration Trials Draft Report. Addis Ababa, Ethiopia.
- ATA (Agricultural Transformation Agency). 2014. The New Agricultural Input Sales System. Technical report. Addis Ababa, Ethiopia.
- Atsbaha Gebreselassie and Tessema Bekele. 2014. A Review of Ethiopian Agriculture: Roles, Policy and Small scale Farming Systems. *Global-growing Organization*, 4(2):36-65.
- Ayinde, O.E., Adewumi, M.O., Olatunji, G.B. and Babalola, O.A. 2010. Determinants of adoption of downy mildew resistant maize by Small-Scale Farmers in Kwara State, Nigeria. *Global Journal of Science Frontier Research*, 10(1): 32-35
- Bayissa Gedefa. 2014. A double-hurdle approach to modeling of improved *teff* technologies adoption and intensity use: The case of Diga district of East Wollega Zone, Ethiopia. *Global Journal of Environmental Research*, 8(3): 41-49.
- Bekabil Fufa, Befekadu Behute, Simons, R. and Tareke Berhe. 2011. Strengthening *Teff* Value Chain in Ethiopia: *Teff* Diagnostic Report. ATA, Addis Ababa, Ethiopia.
- Bekele Shiferaw, Silim, S., Muricho, G. and Audi, P. 2007. Assessment of the adoption and impact of improved pigeon pea varieties in Tanzania. *Journal of SAT Agricultural Research*, 5(1):1-27
- Belay Kassa. 2004. Resettlement of peasants in Ethiopia. *Journal of Rural Development*, 27(2): 223-228.
- Berhane Hailu. 2009. The impact of agricultural policies on smallholder innovation capacities: The case of household level irrigation development in two communities of Kilte Awlaelo Woreda, Tigray regional state, Ethiopia. MSc Thesis, University of Wageningen.
- Berhanu Gebremedhin and Swinton, S.M. 2003. Investment in soil conservation in Northern Ethiopia: The role of land tenure security and public programme. *Journal of Agricultural Economics*, 29(1):69-84.
- Berihun Kassa, Bihon Kassa and Kibrom Aregawi. 2014. Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. *International Journal of Food and Agricultural Economics*, 2(4):91-106

- Blazy, J., Dorel, M., Salmon, F., Ozier-Lafontaine, H., Wery, J. and Tixier, P. 2010. A farm model for ex ante assessment of agro-ecological innovations and its application to banana farms in Guadeloupe. *Agricultural Systems*, 103(4):221-232.
- Brkalem Shewatatek. 2015. Econometrics model on determinants of adoption of improved soil and water conservation practices: The case of Boloso-Sore Woreda, Woliata Zone, Ethiopia. *Scholarly Journal of Scientific Research and Essay*, 4(2): 35-42.
- Burke, W.J. 2009. Triple hurdle model of smallholder production and market participation in Kenya's dairy sector. ProQuest, Kenya.
- Byerlee, D., Spielman, D., Dawit Alemu and Gautam, M. 2007. Policies to Promote Cereal Intensification in Ethiopia: A review of Evidence and Experience. IFPRI Discussion Paper 00707. Washington, DC.
- Costanza, S.H., Dewet, J.M. and Harlan, J. 1979. Literature review and numerical taxonomy of *eragrostis teff*. *Economic Botany*, 33(4):413-424.
- Cragg, J.G. 1971. Some statistical models for limited dependent variables with application to the demand for durable goods. *Journal of the Econometric Society*, 39(5): 829-844.
- CSA (Central Statistical Agency). 2011. Population size by Age, Area and Density by Region, Zone and District. Addis Ababa, Ethiopia.
- CSA (Central Statistical Agency). 2012. Summary and Statistical Report of the Population and Housing Census. Addis Ababa, Ethiopia.
- CSA (Central Statistical Agency). 2013. Agricultural Sample Survey: Area and Production of Major Crops, Meher Season. Vol. I. Addis Ababa, Ethiopia.
- CSA (Central Statistical Agency). 2016. Agricultural Sample Survey: Area and Production of Crops, Main Season. Addis Ababa, Ethiopia.
- Dasgupta, S. 1989. *Diffusion of Agricultural Innovations in Village India*. Wiley Eastern.
- Dawit Alemu, Abebe Atilaw and Setotaw Ferede. 2007. The *Teff* Seed System: Challenges and Opportunities. pp. 291-304. In: Kebebew, A., Solomon, C. and Zerihun, T. (eds.), *Proceeding of the 2nd International Workshop, Achievements and Prospects of Teff Improvement*, 7-9 November 2011. Debre Zeit, Ethiopia.
- Debelo Duressa. 2015. Analysis of factors influencing adoption of quncho *teff*: The Case of Wayu Tuqa District. *International Journal of African and Asian Studies*, 12:20-28.

- Demeke, M. and Di Marcantonio, F. 2013. Analysis of incentives and disincentives for *teff* in Ethiopia. Technical notes series, FAO, Rome.
- Ermias Tesfaye. 2013. Adoption of improved sorghum varieties and farmers' varietal trait preference: The case of Kobo District, North Wolo Zone, Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- Feder, G., Just, R. and Zilberman, D. 1985. Adoption of agricultural innovations in developing countries. *Journal of Economic Development and Cultural Change*, 33(2): 255-298.
- Ghadim, A.K. and Pannell, D.J. 1999. A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics*, 21(2): 145-154
- Ghimire, R., Wen-chi, H. and Shrestha, R. B. 2015. Factors affecting adoption of improved rice varieties among rural farm households in Central Nepal. *Rice Science*, 22(1): 35-43.
- Greene, W. H. 2003. *Econometric Analysis*, 5th Edition. Macmillan, New York, USA.
- Guerre, E. and Moon, H. R. 2006. A study of semi-parametric binary choice model with integrated covariates. *Econometric Theory*, 22(4):721-742.
- Gujarati, D. 2009. *Basic Econometrics*, 5th Edition. Tata McGraw-Hill, New York, USA.
- Gujarati, D. and Porter, C. 2010. *Essentials of Econometrics*, 4th Edition. McGraw-Hill, New York, USA.
- Guush Berhane, Zelekawork Paulos, Kibrom Tafere and Seneshaw Tamiru. 2011. Food Grain Consumption and Calorie Intake Patterns in Ethiopia. ESSP II Working Paper 23. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- Hailu Beyene. 2008. Adoption of improved *teff* and wheat production technologies in crop and livestock mixed systems in Northern and Western Shewa Zones of Ethiopia. Doctoral Dissertation, University of Pretoria, South Africa.
- Hassen Beshir, Bezabih Emana, Belay Kassa and Jema Haji. 2012. Determinants of chemical fertilizer technology adoption in North Eastern highlands of Ethiopia. *Journal of Research in Economics and International Finance*, 1(2):39-49.
- Hassen Beshir. 2014. Factors affecting adoption and intensity of use of improved forages in North East Highlands of Ethiopia. *American Journal of Experimental Agriculture*, 4(1): 12-27.
- Hauenstein, S. 2015. Assessing the resilience of *teff* value chain in Ethiopia. MSc Thesis, Swiss Federal Institute of Technology, Zurich, Switzerland.

- Holden, S. and Lunduka, R. 2012. Do fertilizer subsidies crowd out organic manures? The case of Malawi. *Agricultural Economics*, 43(3):303-314.
- Hopman, E., Dekking, L., Blokland, M.L., Wuisman, M., Zuijderduin, W., Koning, F. and Schweizer, J. 2008. *Teff* in the diet of celiac patients in the Netherlands. *Scandinavian Journal of Gastroenterology*, 43(2): 277-282.
- Idrisa, Y. L., Shehu, H. and Ngamdu, M. B. 2012. Effects of adoption of improved maize seed on household food security in Gwoza local government area of Borno State, Nigeria. *Global Journal of Science Frontier Research*, 12: 5-12.
- Jones, A.M. 1989. A double-hurdle model of cigarette consumption. *Journal of Applied Econometrics*, 4: 23-29.
- Kafle, B. 2011. Factors affecting adoption of organic vegetable farming in Chitwan District, Nepal. *World Journal of Agricultural Sciences*, 7(5): 604-606
- Kaleab Baye. 2014. *Teff* Nutrient Composition and Health Benefits. ESSP II working paper. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- Kapalasa, G.E. 2014. Assessing factors influencing farmers' adoption of improved soybean varieties in Malawi. *Scholarly Journal of Agricultural Science*, 4(6):339-349.
- Kebebew Assefa, Sherif Aliye, Getachew Belay, Gizaw Metaferia, Hailu Tefera and Sorrells, M. E. 2011. Quncho: The first popular *teff* variety in Ethiopia. *International Journal of Agricultural Sustainability*, 9(1):25-34.
- Kothari, C. R. 2004. *Research Methodology: Methods and Techniques*, 2nd Edition. New Age International, New Delhi, India.
- Kudi, T.M., Bolaji, M., Akinola, M.O. and Nasa, I.D. 2011. Analysis of adoption of improved maize varieties among farmers in Kwara State, Nigeria. *International Journal of Peace and Development Studies*, 1(3): 8-12.
- Lavison, R. 2013. Factors influencing the adoption of organic fertilizers in vegetable production in Accra. MSc Thesis, Accra, Ghana.
- Leake Gebreselassie and Adam Bekele. 2015. Factors determining allocation of land for improved wheat variety by smallholder farmers of northern Ethiopia. *Journal of Development and Agricultural Economics*, 7(3):105-112
- Maddala, G.S. 1992. *Introduction to Econometrics*, 2nd edition. Macmillan, New York, USA.

- Mekuria Aweke. 2013. Factors influencing adoption of improved maize varieties in Goro-Gutu Woreda of Eastern Hararghe. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- Mengistu Ketema and Bauer, S. 2012. Determinants of adoption and labour intensity of stone-terraces in Eastern Highlands of Ethiopia. *Journal of Economics and Sustainable Development*, 3(5): 7-17.
- Mignouna, D.B., Manyongl, V.M., Mutabazi, K.D. and Senkondo, E.M. 2011. Determinants of adopting imazapyr-resistant maize for Striga control in Western Kenya: A double-hurdle approach. *Journal of Development and Agricultural Economics*, 3(11): 572-580.
- Miller, D. 2010. *Teff Guide, 3rd Edition*. Teff Grass Crop Overview and Forage Production Guide. Seed Company, Woodland. Retrieved from <http://www.cawestseed.com/teff/>.
- Minten, B., Stifel, D.C. and Seneshaw Tamru. 2012. Structural Transformation in Ethiopia: Evidence from Cereal Markets. ESSP II Working Paper 39. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- Minten, B., Seneshaw Tamru, Ermias Engida and Tadesse Kuma. 2013. Ethiopia's Value Chains on the Move: The Case of *Teff*. ESSP II Working Paper 52. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- MoA (Ministry of Agriculture). 2010. Crop Variety Register, Animal and Plant Health Regulatory Directorate. Addis Ababa, Ethiopia.
- Njane, P.W. 2007. Determinants of adoption of improved wheat varieties and fertilizer use by smallholder farmers in Njoro and Kieni West, divisions of Kenya. Doctoral Dissertation, Egerton University, Kenya.
- Nkonya, E., Schroeder, T. and Norman, D. 1997. Factors affecting adoption of improved maize seed and fertilizer in Tanzania. *Indian Journal of Agricultural Economics*, 48(1):1-12.
- OKARD (Office of Kobo Agricultural and Rural Development). 2015. Socio-economic Profile Description of Kobo District of Amhara Region, Ethiopia.
- Piccinin, D. 2002. More about Ethiopian food : *Teff*. *EthnoMed*, Ethiopian Food.
- Rafael, N. 2011. Determinants of agricultural technology adoption in Mozambique. Post-Doctoral Research Fellow. IFPRI, Maputo, Mozambique.
- Ray, G. L. 2001. *Extension Communication and Management, 2nd Edition*. Prokash, Naya, Calcutta.
- Rogers, E. 1983. *Diffusion of Innovations, 2nd Edition*. Free press, New York, USA.

- Rose, J. 2011. Traditional food profiles: *Teff*. From <http://www.traditionalfood.com/profile/teff>.
- Samson, P., Katengeza, J., Mangisoni, H., Girma, T., Kassie, T., Sutcliffe, C., Langyintuo, A., Rovere, R.L. and Mwangi, W. 2012. Drivers of improved maize variety adoption in drought prone areas of Malawi. *Journal of Development and Agricultural Economics*, 4(14):393-403.
- SARC (Sirinka Agricultural Research Center). 2015. Annual report, Unpublished. Sirinka, Ethiopia.
- Schmidt, E. and Kedir, M. 2009. Urbanization and Spatial Connectivity in Ethiopia: Urban Growth Analysis Using GIS. ESSP II Working Paper. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- Setotaw Ferede. 2013. Technological Change and Economic Viability in *Teff* Production. pp. 255-273. In: Kebebew, A., Solomon, C. and Zerihun, T. (eds.), *Proceeding of the 2nd International Workshop, Achievements and Prospects of Teff Improvement*, 7-9 November 2011. Debre Zeit, Ethiopia.
- Sibanda, M., Mushunje, A. and Mutengwa, C.S. 2016. Factors influencing the demand for improved maize open pollinated varieties (OPVs) by smallholder farmers in the Eastern Cape Province, South Africa. *Journal of Cereals and Oilseeds*, 7(2):14-26.
- Solomon Asfaw, Bekele Shiferaw, Simtowe, F. and Messia Hagos. 2011. Agricultural technology adoption, seed access constraints and commercialization. Evidence from chickpea technologies in Ethiopia. *Journal of Development and Agricultural Economics*, 3(9): 436-447.
- Storck, H., Bezabih Emana, Berhanu Adnew, Borowiecki, A. and Shimelis Welde Hawariat. 1991. Farming systems and farm management practices of small-holders in the Hararghe Highlands. *Farming systems and resource Economics in the tropics*. Wissenschafts, Germany.
- Sulo, T., Koech, P., Chumo, C. and Chepnengo, W. 2012. Socio-economic factors affecting the adoption of agricultural technologies among women in Marakwet County Kenya. *Journal of Emerging Trends in Economics and Management Sciences*, 3(4): 35-43
- Susan, C. 2011. Technical and allocative efficiency of smallholder maize farmers in Zambia. MSc Thesis, University of Zambia, Lusaka, Zambia.

- Swanson, B., Bentz, R. and Sofranko, A. 1997. Improving Agricultural Extension: A Reference Manual. Food and Agriculture Organization of the United Nations, Rome.
- Tadesse Adgo. 2008. Farmers evaluation and adoption of improved onion production package in Fogera district, Northern Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- Tareke Berhe, Zewdie Gebretsadik, Edwards, S. and Hailu Araya. 2011. Boosting *Teff* Productivity Using Improved Agronomic Practices and Appropriate Fertilizer. Pp. 133–140. In: Kebebew, A., Solomon, T. and Chanyalew, Z. (eds.), *Proceedings of the 2nd International Workshop in Achievements and Prospects of Teff Improvement*, November 7-9, 2011, Debre Zeit, Ethiopia.
- Teklewold Hailemaiam, Legesse Dadi, Alemu Yami and Dana, N. 2006. Determinants of adoption of poultry technology: A double-hurdle Approach. *Livestock Research for Rural Development*, 18(3).
- Tesfaye Teklu, Fassil Kelemework, Abera Deresa, Elias Zerfu, Kiflu Bedane and Legesse Dadi. 2001. *Teff* Technology Transfer and Adoption. Pp. 255-264. In: Hailu Tefera, Getachew Belay and Sorrells, M. (eds.), *Proceedings of the International Workshop on Teff Genetics and Improvement*, 16-19 October 2000. Addis Ababa, Ethiopia.
- Tesfaye Tadesse. 2013. Participatory variety selection of potato (*solanum tuberosum* L.) in southern Ethiopia. *Journal of Agriculture-Food and Applied Science*, 1(1):1-4.
- Tewodaj Moges, Cohen, M.J., Birner, R., Mamusha Lemma, Randriamamonjy, J., Fanaye Tadesse and Zelekawork Paulos. 2009. Agricultural Extension in Ethiopia through Gender and Governance Lens. ESSP II Discussion Paper, International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.
- Thirtle, C.D. and Ruttan, V.W. 1987. *The Role of Demand and Supply in the Generation and Diffusion of Technology Change*. Taylor Academic Publisher, New York, USA.
- Tsegaye Mulugeta and Bekele Hundie. 2012. Impacts of Adoption of Improved Wheat Technologies on Households' Food Consumption in Southeastern Ethiopia. *Selected Poster Prepared for Presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference*, 18-24 August, 2012. Brazil.

- Tsibuk Berhe. 2015. Factors affecting adoption of quncho *teff* variety: The case of Medebayzana Woreda, North-Western Administrative Zone of Tigray Region, Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- USAID (United States Agency for International Development). 2012. Improved Grain Varieties: Impact through Research and Development, tool for transformation, capacity to improve agriculture and food security. Addis Ababa, Ethiopia.
- Vavilov, N.I. 1951. *The Origin, Variation, Immunity and Breeding of Cultivated Plants*. Roland Press, New York, USA.
- Verkaart, S., Bernard, G., Mausch, K. and Jeffrey, D. 2016. Welfare impact of improved chickpea adoption in Ethiopia. *Food policy*, 66(2):50-61
- WB (World Bank). 2008. Agriculture for Development. World Development Report, Washington, DC.
- WB (World Bank). 2013. Ethiopia Rural Socioeconomic Survey Report. Addis Ababa, Ethiopia.
- WB (World Bank). 2016. World Development Report. Does Digital Technologies Transform Agriculture? Washington, D.C
- Wooldridge, J.W. 2002. *Econometric Analysis of Cross Section and Panel Data*. Massachusetts Institute of Technology Press, Cambridge, USA.
- Worku, I., Dereje, M., Berhane, G., Minten, B. and Taffesse, A. 2014. *Teff* and its Role in the Agricultural and Food Economy. Ethiopian Research Institute. (Unpublished).
- Yaregal Mulu. 2011. Adoption of improved varieties of maize: The case of Dilla zuria Woreda, SNNPR, Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
- Yenealem Kassa, Ranjan, S. and Belaineh Legesse. 2013. Determinants of adoption of improved maize varieties for male headed and female headed households in West Harerghe Zone, Ethiopia. *International Journal of Economic Behavior and Organization*, 1(4): 33-38.
- Yitayal Abebe and Adam Bekele. 2015. Analysis of adoption spell of improved common bean varieties in the central rift valley of Ethiopia: A duration model approach. *Journal of Agricultural Economics and Development*, 4(3):037-043.
- Yu, B. and Nin-Pratt, A. 2014. Fertilizer adoption in Ethiopia's cereal production. *Journal of Development and Agricultural Economics*, 6(7):318-337.
- Zerihun, A.W., Kibret, H. and Wakiaga, J. 2014. Ethiopia. African Economic Outlook. <http://www.africaneconomicoutlook.org/en/terms conditions/>, 1.11.2015.

7. APPENDICES

Appendix I: Tables

Appendix Table 1. Multicollinearity test results for the continuous explanatory variables

Variables	Co-linearity Statistics	
	VIF	1/VIF
Age of the household head	1.98	0.506
Family labor in adult equivalent	1.40	0.714
Off/non-farm income	1.05	0.956
Farming experience	2.05	0.488
Cultivated land size	2.39	0.418
Proportion of <i>teff</i> cultivated land	1.95	0.512
Livestock holding in TLU	1.42	0.704
Frequency of extension contact	1.02	0.979
Distance from the nearest market	1.20	0.830
Mean VIF	1.61	

Source: Data result, 2016

Appendix Table 2. Multicollinearity test results for dummy explanatory variables

Variables	Sex	Education	Demonstration Participation	Seed availability	Credit	Organization member	Yield
Sex	1	0.033	0.022	0.003	-0.205	0.016	-0.111
Education		1	-0.276	-0.132	0.011	0.083	-0.294
Demonstration Participation			1	0.262	-0.032	0.195	0.102
Seed availability				1	0.039	-0.254	0.002
Credit					1	0.090	-0.102
Organization member						1	0.147
Yield							1

Source: Data result, 2016

Appendix Table 3. Conversion factors for adult-equivalent

Age group (years)	Conversion factor	
	Male	Female
<10	0.60	0.60
10-13	0.90	0.80
14-16	1.00	0.75
17-50	1.00	0.75
>60	1.00	0.75

Source: storck *et al*, 1991

Appendix Table 4. Conversion factor for livestock units

No	Livestock category	Conversion factor(TLU)
1	Sheep and Goat (adult)	0.13
2	Sheep and Goat (young)	0.06
3	Heifer	0.75
4	Bull	0.75
5	Cow and oxen	1.00
6	Donkey (adult)	0.70
7	Donkey (young)	0.35
8	Chicken	0.013
9	Camel	1.25
10	Calves	0.25

Source: storck *et al*, 1991

Appendix Table 5. Test statistics for comparison of double-hurdle with Tobit Model

	Tobit	Double hurdle	
		Probit	Truncated
Wald/LR χ^2	143.61	131.22	78.24
Prob > χ^2	0.000	0.000	0.000
LOG-L	-13.17	-38.24	70.39
Number of observations (N)	150	150	72
Log likelihood ratio statistics $\Gamma = 90.64 > \chi^2(16) = 32$			

Source: Data result, 2016

Appendix II: Survey Questionnaire

1. Household characteristics

- 1.1. Kebele of the household head_____.
- 1.2. Type of respondents: 0) Improved *teff* non-adopters 1) Improved *teff* adopters
- 1.3. Sex of the household head: 0) Female 1) Male
- 1.4. Age of the household head: _____ years.
- 1.5. Educational level of the household head: 0. Illiterate 1. Read and write
2. Primary (Grade 1-8) 3. Grade 9 and above
- 1.6. Marital status the household: 1. Single 2. Married 3. Widow 4. Divorced
- 1.7. Religion: 1. Muslim 2. Orthodox 3. Protestant 4. Others_____

1.8. Family size: Male _____ Female _____ Total _____

1. Number of children less than 10 years: Male _____ Female _____ Total _____

2. Number of children from 10-13 years: Male _____ Female _____ Total _____

3. Number of children from 14-16 years: Male _____ Female _____ Total _____

4. Number of adult from 17-50 years: Male _____ Female _____ Total _____

5. Number of elderly > 50 years: Male _____ Female _____ Total _____

1.8.1. Did all your household members participate in farming work? 0) No 1) Yes

1.8.2. If yes, how many of them participated _____ (in number).

1.8.3. How many family members go to school? _____ (in number).

1.8.4. Did you face labor shortage problem in *teff* production? 0) No 1) Yes

1.8.5. During which farm operation do you face labor shortage? 1) Land preparation

3) Plantation 4) Weeding 5) Harvesting 6) Threshing 8. Others (specify) _____

1.8.6. If yes (1.9.11), how do you solve labor shortage problem? 1) By hiring 2) asking for cooperation (Jigi /Debo) 3) Assistance from relative 4) Combination of all 5) Others (Specify)

2. Off/non-farm income

2.1. Have you involved in off/non-farm activities in 2015/16 production season? 0) No 1) Yes

2.2. If yes, what is the type of off/non-farm activity you involved in and the income earned?

No	Type of off-farm activities	Income earned in birr
1	Petty trade	
2	Handcraft	
3	Charcoal and firewood	
4	Daily labor	
5	Remittance	
6	Selling beverage	
7	Causal labor work	
8	Others	
Total off/non-farm income		

3. Income from sale of crops in 2015/16 E.C

No	Type of products	Income earned in birr
1	Cereals	
2	Pulses	
3	Fruits and vegetables	
4	Others	
Total cash income in birr		

4. Income from sales of livestock product in 2015/16

No	Product type	Amount collected	consumed	Sold	Unit price	Total revenue	Purpose of sold
1	Milk						
2	Cheese						
3	Butter						
4	Egg						
5	Honey						
6	Hide and skin						
7	Others						
Total cash income							

*Purpose 1) for purchasing farm inputs 2) for settling debts 3) for buying clothes for family
4) To buy food grains 5) others (Specify) _____

5. Farming Experience

5.1. Farming experience of the household head in years (general farming experience) ____ years.

5.2. Farming experience of the household head in *teff* farming ____ years.

6. Cultivated land size

6.1. Do you own land? 0) No 1) Yes

6.2. Total land Size _____ in Tsimad and _____ number of plots

1. Cultivated land size _____ Tsimad, _____ plots.

A. land allotted to annual crops _____ Tsimad, _____ plots.

B. land allotted to tree crops _____ Tsimad, _____ plots.

C. land allocated to cereals _____ Tsimad _____ plots.

D. land allocated to *teff* _____ Tsimad _____ plots.

E. land allocated to improved *teff* _____ Tsimad _____ plots.

2. Fallow land _____ Tsimad, _____ plots.

3. Homestead _____ Tsimad, _____ plots.

4. Irrigated land _____ Tsimad, _____ plots 7. If others specify _____

7. Livestock Holding

7.1. Did you own livestock? 0) No 1) Yes

7.2. If yes, what is the total number of livestock you own in TLU and annual income including their products in 2015/16?

Livestock type	Total number	Total sold	TLU	Selling price	Total income	Purpose
Oxen						
Cows						
Camel						
Donkey						
Sheep						
Goats						
Calves						
Poultry						
Chicken						
Heifer						
Bull						
Calves						
Others						
Total						

*Purpose 1) for purchasing farm inputs 2) for settling debts 3) for buying clothes for family

4) To buy food grains 5) others (Specify) _____

8. Extension service

8.1. Have you ever consulted extension agents on agricultural activities? 0) No 1) Yes

8.2. If yes, how frequently do the extension agents visit you? _____

8.3. If no, why? Specify the reason _____

8.4. When does extension agent visit you? 1) During planting for technical advice 2) during input provision 4. During land preparation 5. During harvesting 6. Others (specify)

8. 5. Types of extension messages given by the agents?

1. Fertilizer use 0) No 1) Yes 2. Insecticide use 0) No 1) Yes

3. Improved seed use 0) No 1) Yes 4. Manure use 0) No 1) Yes

5. Land use practices 0) No 1) Yes 6. Other (specify)

9. Participation on demonstrations and training

9.1. Have you ever attended any demonstration trial? 0) No 1) Yes

9.2. Who organize the demonstration A. Extension agents B. NGO's C. SARC D. Others

9.3. What benefit did you get from the demonstration?

1. Production increment 2. Getting locally suitable *teff* variety

3. Getting preferred improved *teff* varieties 4. Getting comparative advantage of crops

5. Others specify _____

9.4. Have you ever received training in *teff* production in the last five years? 0) No 1) Yes

9.5. If yes, how many times _____ Who arranged for you? 1. OKARD 2. Research institutions
3. NGO 4. Others _____

9.6. Distance to farmers training center _____ Km, _____ minutes.

10. Improved seed availability

10.1. Is improved *teff* seed available on time in your area? 0) No 1) Yes

10.2. If yes, from where did you get improved *teff* seeds? 1. OKARD 2. Research Centre
3. Own 4. Market 5. Neighbors 6. NGOs 7. Others, specify _____

10.3. If no, specify the reason _____

11. Distance from the nearest market

11.1. Do you sell *teff* this last cropping season? 0) No 1) Yes

11.2. If yes where is your output marketed?

1. At farm gate 2. Local market 3. District market 4. Through cooperative services
5. Other, specify _____

11.3. How far do you travel to buy improved *teff* seed (round trip) and to sell your agricultural product (round trip)? _____ Km.

11.4. Do you get information on *teff* grain selling price 0) No 1) Yes

11.5. If yes, specify your source of information and indicate how often you get access to it?

No	Source of information	How often you get access to it?			Rank
	Rarely (1)	Sometimes (2)	Often(3)	Very often (4)	
DA					
Traders					
Neighbor farmers					
Cooperative society					

12. Access to credit

12.1. Did you receive credit facility from financial institutions in 2015/16 year? 0) No 1) Yes

12.2. If your answer to question 12.1 is yes, is the amount of loan sufficient? 0) No 1) Yes

12.3. For what purpose did you use the credit? 1. For purchasing fertilizer 2. For purchasing improved seeds 3. For purchasing chemicals 4. Other purpose (Specify)

12.4. If your answer to question number 12.1 is no, why you did not obtain?

1. I don't need credit 2. I can use other sources
3. Inadequate loan amount 4. High interest charge 5. Lack of collateral

6. Other reason, please specify_____

12.5. Have you obtained credit improved *teff* variety in kind? 0) No 1) Yes

12.6. If your answer is yes for question number 12.5, from where you get and how much did you get? Source _____ Amount (in Kg) _____

13. Membership to organizations

13.1. Are you a member of any social organizations? 0) No 1) Yes

13.2. If yes, what service do you get from the organizations you belong to?

1. Loans/credit 2. Farm inputs (fertilizer, chemicals, improved seeds) 3. Labour

4. Others (specify) _____

13.3. In which of the following social organization do you participate?

1. Farmers' association/cooperatives 2. Credit and saving 3. Irrigation group

4. Ikub and idir 6. Others (specify) _____

13.4. Frequency of participation? 0) Never 1) Always 2) Sometimes

14. Adoption of *teff* production package components

14.1. What planting method do you used last cropping season? 1. Row planting 2. Broadcast

14.2. What is your level of adoption of the following *teff* production package practices by 2015/16?

No	Package practices	Rate of application(farmers practice) per ha or tsimad	reason for not implementing according to the recommendation
1	Seed rate		
2	Fertilizer rate	DAP	
		UREA	
3	Chemical insecticide		
4	Frequency of weeding		
5	Spacing between row		

15. Information specific to *teff* Production

15.1. When did you start growing improved *teff* varieties? _____ Years

15.2. What was the source of your seed? 1. Own 2. Purchase 3. Other (specify) _____

15.3. Did you get the variety that you wanted in 2015/16? 0) No 1) Yes

15.4. If no why? 1. Seed unavailable 2. Seed too expensive 3. Poor quality 4. Other (specify)

15.5. Did you use improved *teff* (2015/16 cropping season)? 0) No 1) Yes

15.6. If yes, which improved variety?

1. *Quncho* 2. *Boset* 3. *Zobel* 4. All varieties 5. Others (specify) _____

15.7. If yes, approximately how many plots of land did you allocate for planting the improved *teff* variety? _____plots and _____timad.

15.8. If no, Local varieties _____in timad.

15.9. Do you think that the improved *teff* variety is better than local variety in terms of the following characteristics?

- | | | | | |
|-----------------------|-------|--------|---------------------------------|--------------|
| 1. Yield capacity | 0) No | 1) Yes | 2. Drought resistance | 0) No 1) Yes |
| 3. Maturity period | 0) No | 1) Yes | 4. Resistance to diseases/weeds | 0) No 1) Yes |
| 5. Lodging resistance | 0) No | 1) Yes | | |

15.10. What is the productivity of *teff* per hectare without improved seed? ____Qt/ha

15.11. What is the productivity of *teff* per hectare with improved seed? ____Qt/ha

15.12. Does the use of improved varieties require additional labor than the usual operation?

0) No 1) Yes

16. What is your perception towards the adoption of improved *teff* in your locality?

Thank you very much!