ADOPTION OF IMPROVED POTATO VARIETIES BY SMALLHOLDER FARMERS: THE CASE OF CHILGA WOREDA, NORTH GONDER ZONE, AMHARA REGION, ETHIOPIA

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I dedicated this thesis document to my beloved family.

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BIOGRAPHICAL SKETCH

The author was born in December 04, 1991 G.C in Chilga *woreda*, North Gonder Zone, Amhara National Regional State. She attended her primary and secondary education (1-10th grade) in Chonchok Elementary and Secondary School; and Preparatory education (11-12 grade) in Aykel Preparatory School.

After she successfully passed the Ethiopian School Leaving Certificate Examination (E.S.L.C.E.), she joined Wollo University in 2012 and graduated with Bachelor Degree of Science in Agricultural Economics in July, 2014. After her graduation, she was employed by Wollo University as a Graduate Assistant in October 2014 and served for 2 years. She had been working there until she joined Haramaya University in October 2016 to pursue her MSc. study in Agricultural and Applied Economics.

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ACRONYMS AND ABBREVIATIONS

AERC	African Economic Research Consortium
AIC	Akaki Information Criteria
ANRS	Amhara National Regional State
CC	Contingency Coefficient
CWOARD	Chilga *Woreda* Office of Agriculture and Rural Development
CIP	International Potato Center
CSA	Central Statistical Agency
EIAR	Ethiopian Institute of Agricultural Research
Ha	Hectare
IMR	Inverse Mills Ratio
IPV	Improved Potato Variety
ISPV	Improved Sweet Potato Variety
Km	Kilometer
LR	Likelihood Ratio
MOA	Ministry of Agriculture
NGO	Non-Governmental Organization
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor

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ABSTRACT

Potato is one of most important food crops in the world in general and Ethiopia in particular. However, low productivity of potato is one of the major constraints in potato production in Ethiopia. Encouraging adoption and wider diffusion of potato technologies are important policy measure to address the problem. However, adoption and intensity of adoption of improved potato varieties are constrained by many factors. Hence, in this study an effort was made to evaluate adoption decision and intensity of use of improved potato seed varieties. A two stage random sampling technique was used to select 160 sample potato producers from Chilga woreda. Descriptive statistics were used to analyze characteristics of adopters and non-adopters. Double hurdle model was used to identify factors affecting adoption decision and intensity of adoption of improved potato varieties. Adoption status and intensity of improved potato varieties was found to be 53% and 63.8% respectively. The result of the model indicated that educational status of the household head, land holding size, participation in off/non-farm activities, livestock holding size, frequency of extension contact, membership to institution/ organization and perception on yield capacity significantly and positively influenced adoption decision of improved potato varieties. On the other hand labor availability, land holding size and livestock holding size significantly and positively influenced intensity of improved potato varieties. Whereas, age of the household head and distance to the nearest market significantly and negatively affected intensity of adoption of improved potato varieties. The study suggested government and stakeholders to focus on arranging short term training program, strengthening the provision of formal education, encouraging the use of labor saving technologies, improving crop-livestock production system, encouraging farmers participation in off/non-farm income generating activities, enhancing frequency of extension contact, strengthening farmers' organization, providing good transport facilities for farmers through infrastructural development.

Key words: Adoption, Intensity, Double Hurdle Model, Improved Potato Varieties, *Chilga*

1. INTRODUCTION

1.1. Background of the Study

Ethiopia is one of the fastest growing economies in Africa. In the last decade, the Ethiopian economy registered a growth of 11 percent per annum on average in Gross Domestic Product (GDP) (MoFED, 2014) compared to 3.8 percent in the previous decades (World Bank, 2015). This growth is mainly supported by the agricultural sector. The sector is most crucial for the country's overall economy development, food security and the livelihoods of its people, accounting for 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). Moreover, 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.

Root and tuber crops are essential part of the farming system in Ethiopia. It provides a substantial part of the country's food supply, and are also an important source of animal feed and industrial products. In 2016/17 production season root crops accounted for about 229.08 thousand ha of area coverage and 46.3 million qt of volume of production (CSA, 2017).

Among several root and tuber crops, potato (*Solanum tuberosam L.*) plays significant dietary role for human beings provided that good quality and high yield is guaranteed. Potato is among the major and third most important food crops produced in the world on the basis of production after rice and wheat and it is a food security crop in developing countries, including Ethiopia (Devaux *et al*., 2014). In Ethiopia the total production of potato was 943,233 tons with an average productivity of 13.5 ton/ha in 2015/16 production season. The area under potato was 70,132 ha cultivated by 1.4 million households in the main cropping season of 2015/16. During the same period, it ranked first in area coverage and third in both total production and productivity among the root crops grown in Ethiopia (CSA, 2016).

Nutritionally, potato provides more calories, vitamins, and nutrients per unit area than any other staple crops (Sen *et al*., 2010). Hence, it contributes towards efforts of ensuring food and nutrition security. In Ethiopia, potato is becoming a prominent source of income since the crop is the most important cash crop for smallholder farmers in the mid-altitude and highland areas of the country (Gildemacher *et al*., 2009).

Potato has been considered as a strategic crop by the Ethiopian government aiming at enhancing food security and economic benefits to the country (Helen, 2016). As the population grows rapidly, increased productivity of potatoes can improve the livelihood of smallholder potato farmers and is required to meet the growing demand (Gildemacher *et al*., 2009). The potato subsector is potentially of great importance for pro-poor growth since it is the best option for many households to generate income in Ethiopia. Potato has multiple benefits for low income households and where land shortage is a constraint. Potato grows quickly, has relatively high yield, and contains more energy and protein per unit area when compared to cereal crops. Therefore, it plays a vital role in ensuring food security, which is a major concern for the country.

Despite the production potentials and importance of potato crop for the country, its national average productivity is low (13.7 ton/ha) as compared to the potential yield (40 ton/ha) (CSA, 2015). It is true in north western part in general and chilga *woreda* in particular. 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 (Setotaw, 2013; Berihun *et al*., 2014). Agajie *et al.* (2012) indicated that improved varieties of potato provided a two- to seven fold yield advantage over the local varieties.

North western area of the country is the major potato growing area in the Amhara region. North Gonder zone is one of the major potato growing zone in the north western area (Adane *et al*., 2010).Chilga *woreda* is one of the *woreda* in the North Gonder Zone. It is endowed with favorable climatic and natural resource conditions that can grow cereal crops, tuber crops and raising livestock. According to Chilga *woreda* agricultural and Natural Resource Office (2018), the major crops grown include Sorghum, Maize, Barley, Wheat, Potato, Sesame, and Cotton.

In Chilga *woreda* in 2015/16 production season, the total potato production is low which is 565,430 and 28,578 quintals under rain fed and irrigation respectively (CWOARD, 2018).To increase production and productivity of potato and to improve the food security status in this *woreda*, improved potato varieties was introduced in 2006. The known potato varieties produced in the area are Belete, Jalenie and Gudenie.

However, in the study area no attempt has been made to study the adoption of new potato varieties and factors that favor or limit its adoption of improved potato varieties are not yet studied and documented. Therefore, this study was initiated to analyze factors that affect the adoption decision and intensity of use of improved potato seed varieties in the study area.

1.2. Statement of the Problem

Potato can play significant role in ensuring access to food at the household level and can also generate income for smallholders, thereby contributing to the economic sustainability of agricultural systems in developing countries (Thompson and Scoones, 2009). Potato holds great promise for improving the livelihoods of millions of smallholder farmers in the highlands of Ethiopia (Semagn *et al.,* 2015). The potential for high yield, early maturity and excellent food value give the potato great potential for improving food security, increasing household income, and reducing poverty (Devaux *et al*., 2014). Despite its importance, the productivity of the crop is relatively low (CSA, 2015). Many factors contribute to the low yield, including drought (Doss *et al*., 2008; FAO, 2010), frost, hail, pests, diseases (Bekele and Eshetu, 2008), poor production practices and limited access to high quality seed (Gildemacher *et al.*, 2009; Hirpa *et al*., 2010), Low level of adoption of improved potato technology (Abebe *et al.,* 2013).

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 for increasing production and income. The Ethiopian potato research system has released about 31 new potato varieties to address some of these production problems (MOA, 2013). This is done by Ethiopian government with International Potato Center (CIP) to promote adoption of improved potato varieties. Despite of such release, their adoption by farmers in most potato production areas is very low (Abebe *et al*. 2013; Gebremedhin, 2013 and Kolech *et al*., 2015).

Though improved varieties have better yields (Chakraborty *et al*., 2000) and more resistant to late blight (Song *et al.,* 2003), virus and bacterial wilt (Thiele, 1999); most Ethiopian farmers still grow older local cultivars and Nationally, about 77% of Ethiopian potato land is planted to local cultivars each year (Kolech *et al*., 2015). Additionally, the majority of smallholder farmers still grow old varieties (Gildemacher *et al*. 2009; Hirpa *et al.*, 2010). Chilga *woreda* is one of the *woreda* where this situation is observed.

This low rate of adoption decisions of farmers is usually determined by various factors which can be specific to demographic, socio-economic, and institutional and psychological factors. The EIAR recognizes the problem with low adoption rates by ware potato farmers, although the causes have not been fully investigated. Shortage of improved seeds and poor supply systems mentioned as the main limiting factors (Gebremedhin *et al*., 2008). This indicates supply problems and potential adopters not having access to improved varieties as one of the factors hindered adoption rate. The main constraints to accessing improved varieties are lack of availability of healthy seed tubers and poor seed tuber quality (Hirpa *et al*., 2010; Gebremedhin *et al*., 2008). Adoption of improved varieties is hindered by awareness of the availability and use of improved technologies (Hirpa *et al*., 2010), shortage of land (CSA, 2011) and the high prices of healthy seed tubers (Agajie *et al*., 2013).

However, those factors that attributed to low productivity of potato and low rate of adoption can vary from location to location and time to time. In the study area rate of adoption of improved potato variety as well as intensity of adoption have not yet been studied. Therefore, this study is designed to address the prevailing information gap on the subject and contribute to proper understanding of the challenges. Hence based on the information obtained concerned stakeholders can make an intervention and improve adoption and intensity of adoption of improved variety. Hence, in this study factors that affect the adoption decision and intensity of use of improved potato varieties in Chilga *woreda* of north Gonder zone, Amhara National Regional State was analyzed.

1.3. Objectives of the study

The general objective of this study was to evaluate status of adoption of improved potato seed varieties by smallholder farmers' in Chilga *woreda*.

The specific objectives were to:

1. analyze factors influencing adoption decision of improved potato varieties in the study area
2. identify factors determining intensity of adoption of improved potato varieties by smallholder farmers in the study area

1.4. Research questions

In light of the problems and the gaps, this study has been designed and executed to answer the following key research questions:

1. What factors affect the decision to adopt of improved potato varieties in the study area?
2. What factors determine the intensity of adoption of improved potato variety in the study area?

1.5. Significance of the Study

The remarkable productivity growth in the agricultural sector of the world mainly comes from the technological improvement. Adoption can boost production and productivity of crops. Similarly, potato production and productivity is enhanced by different improved technologies.

Thus, the study assumed to produce very important information on location specific factors related to economic, social, institutional factors and perception on improved potato varieties. Therefore, this study will provide important information about the adoption decision and intensity of improved potato varieties in the study area. The findings of this study is used as an input for policy makers in designing future policies and strategies for potato. 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 and intensity of improved potato varieties in particular and other commodities in general. Hence, the information produced from this study will contribute for technology generators, extension agents, input

suppliers and other organization working in agricultural sector to improve their service for the production of potato.

1.6. Scope and Limitation of the Study

This study was undertaken in Chilga *woreda* of North Gonder Zone. One tuber crop namely potato is selected for this study due to the study area's being has great potential for potato production and farmers produce it for consumption purpose and as one of the cash crops. Due to the limitation of resources, the study was mainly based on the information generated from the sample household survey conducted during a single cropping season using a cross-sectional data. Hence, theoretical analyses of this research are largely based on static models. Therefore this study is limited to only adoption and intensity of adoption of improved potato varieties of the target study area.

1.7. Organizations of the Thesis

This thesis contains five chapters. The first chapter basically introduces the background, the statement of the problem, objectives, limitations and significance of the study. The second chapter presents review of literature where relevant materials related with the present study are explored. The third chapter devoted to research methodology. Chapter four contains the presentations and discussions of the findings of this study. The fifth chapter summarizes and concludes the findings, and reflects some recommendations.

2. LITERATURE REVIEW

In this chapter, theoretical reviews of basic concepts and definitions, theoretical perspective of adoption that serve as a basis for the analyses are discussed. In addition potato production in Ethiopia, reviews of analytical methods for agricultural technology adoption, relevant empirical literatures on adoption of agricultural technologies, and conceptual framework of the study are discussed.

2.1. Basic Concepts and Definitions

Agricultural technology adoption: It is described as a decision made to use an innovation in usual farming practice (Feder and Zilberman, 1985).

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 (Ray, 2001).

Improved potato varieties: Potato varieties that have been developed or cleaned up for diseases by IPC in collaboration with National research system since 1970 and are considered to be superior in qualities such as yields, resistance to diseases, dormancy period, maturity period or taste as compared to 'local' or existing varieties. Improved varieties also include those varieties originating from trials conducted by national agricultural research system and selected and adopted by farmers because of their superior qualities but have not been out with the farmers for more than 35 years (Kaguongo *et al.*, 2008).

2.2. Theoretical Perspectives of Adoption

Rogers (1962) defined the adoption process as the mental process an individual passes from the first hearing of about an innovation or technology to a final adoption. In addition, according to the definition by Van den Ban and Hawkins (1996), the adoption process refers to changes that take place within the minds of an individual with regard to an innovation from the moment he/she becomes aware of the innovation to the final decision to continuously use it or not. Adoption of a new innovation being one of the possible outcomes of behavioral change process, involves choice making which implies cognitive engagement (Koch, 1986). Duvel (1975) identified psychological related variables, need, perception and knowledge which according to him are the most important and direct determinants of behavioral change.

Feder *et al*. (1985) 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).

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. According to Saha *et al*. (1994) intensity of adoption refers to the number of technologies practiced or the extent of adopting a specific technology by the same farmer. Feder *et al*. (1985) argues that for divisible technologies, such as improved varieties or chemicals, it is possible to assess the degree of use or intensity within a household. The author also indicated that intensity can be measured as the number of hectares under an improved variety or the amount of inputs applied per hectare.

2.2.1. The classical five stage adoption process

The classical five-stage adoption process model which was formulated by the North Central Rural Sociology Committee (1961) was the dominant model until it was modified by Rogers and shoemaker (1971). According to Campbell (1966) the classical five-stage adoption process model was developed from the recognition that adoption of an innovation often is not an instantaneous act. Rather it is a process that develops over a period of time and influenced by a series of actions. The model composed of the following five stages of adoption process:

1. Awareness Stage: - first hear about the innovation

2. Interest Stage: - seek further information about an innovation
3. Evaluation Stage: - weigh up the advantages and disadvantages of using it
4. Trial Stage: - test the innovation on a small scale and,
5. Adoption Stage: - apply the innovation on a large scale in preference to old methods.

With regard to the relationship of technological attributes with farmers' adoption decision, Rogers (1995) identified five characteristics of agricultural innovations, which are important in adoption studies. These include 1) Relative advantage 2) Compatibility 3) Complexity 4) Trial-ability and 5) Observability. He defines these characteristics as follows:

Relative advantage: Is the degree to which an innovation is perceived as better than the idea it supersedes.
Compatibility: The degree to which the farmer perceives an innovation to be consistent with his/her cultural values and beliefs, traditional management objectives, the existing level of technology, agro ecology and stages of development.
Complexity: The degree to which an innovation is perceived to be complex or difficult to understand and practice by farmers.
Observability: The degree to which results of innovation are visible to farmers.
Trialability: The degree to which the innovation could easily be tried at smaller scale by farmer on his/her farm.

2.2.2. Innovation Decision Process

According to Rogers (1983) there is no sufficient evidence to prove that the above stages exist in the classical five stages theory. Decisions in practice often may be made in a less rational and systematic manner than the stages outlined above. The adoption process does not always follow the above sequence in practice. This indicates that adoption is not a sudden event but a process. Farmers do not accept technology immediately; they need time to think over things before reaching a decision. Due to the above criticism against the classical five stage theory, Rogers and Shoemaker (1971) designed the innovation decision process which was later revised by Rogers (1983) and is presented as follows.

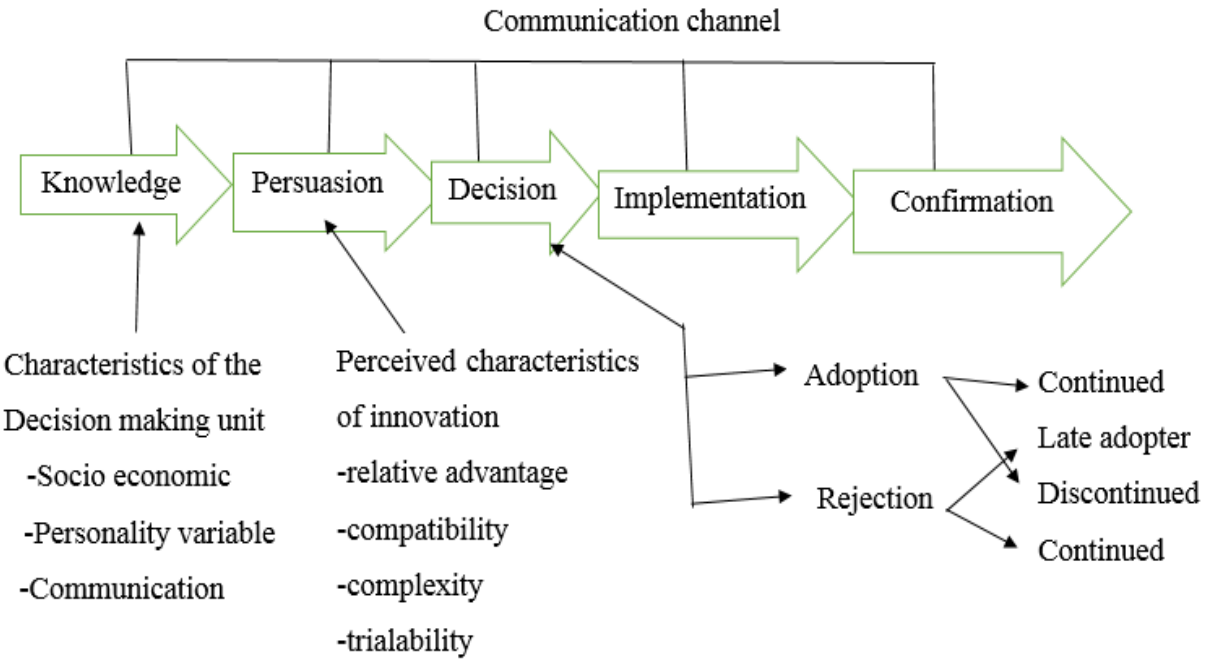

Figure 1.The innovation decision process

Source: Rogres, 1983

The innovation decision is thus the process through which an individual or other decision making unit, extension organization passes from first knowledge of an innovation to forming an attitude towards the innovation, to decision to adopt or reject, to implementation of the new idea, and to the confirmation of the decision (Rogers, 1983). This model has the following five stages:

A. Knowledge occurs when an individual (or other decision-making unit) is exposed to the innovation's existence and gains some understanding of how it functions.
B. Persuasion occurs when an individual (or other decision-making unit) forms a favorable or unfavorable attitude towards the innovation.
C. Decision occurs when an individual (or other decision-making unit) engages in activities that lead to a choice to adopt or reject the innovation.
D. Implementation occurs when an individual (or other decision-making unit) puts an innovation into use.
E. Confirmation occurs when an individual continues to decide to adopt the innovation has been made

The innovation-diffusion model, following from the work of Rogers, holds that access to information about an innovation is the key factor determining adoption decisions. The appropriateness of the innovation is taken as given, and the problem of technology adoption is reduced to communicating information on the technology to the potential end users (Adesina and Zinnah, 1993).

With regard to the concepts related to diffusion, it refers to the spread of an innovation among the members of the social system. The dissemination of agricultural innovations to users is one of the priority areas that deserve attention in agricultural and rural development. The application of improved techniques (innovations) whether it is introduced from within or outside is important for framers to achieve increased production or productivity. A technological innovation consists of both the idea component and the object component (Rogers and Shoemaker, 1971).

Diffusion of an innovation is a multidisciplinary concept of planned social change that is brought about by the spread of new ideas or new technologies throughout the social system. Communication among the change agency and the client system, and further communication within that system results in individuals or groups making a decision whether to adopt or reject the innovation (Gross, 1979 as cited by Kidane, 2001).

2.3. Potato Production in Ethiopia

Potato is regarded as a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit of input with a shorter crop cycle (Hirpa *et al*., 2010.). Potato can play an important role in improving food security and cash income of smallholder potato growers in Ethiopia. As a food crop, potato has a high potential to supply a cheap and quality food within a relatively short period. Potatoes are the perfect food and one of the few that can actually sustain life on its own. Potato is a well-balanced major plant food with a good ratio between proteins and calories, and has substantial amounts of vitamins, especially vitamin C, minerals, and trace elements. Moreover, it has the correct balance of protein calories and total calories.

Potato has long been regarded as a lowly subsistence crop and is still an underexploited food crop. Potato has huge potential to improve food security, income and human nutrition and it is in Ethiopia where the potential of this crop is increasingly being realized and explored by farmers, private investors, and policy makers. While, national average yields are still far below attainable yields, ample opportunities exist to unleash this crop's potential for increased food security and income generation (Teklemariam, 2014).

The North-western area of potato production is situated in the Amhara region. It is the major potato growing area in the country, accounting for about 40% of the potato farmers. South Gonder, North Gonder, East Gojam, West Gojam and Agew Awi are the major potato production zones in this region. Farmers mainly grow local varieties. Large volume of potato is produced in the dry season using irrigation as well as during *belg* (short rainy) season. Potato is also produced in the *Meher* (main growing) season (Helen, 2016).

2.4. Analytical Methods for Agricultural Technology Adoption

Different researchers used different models for analyzing the determinant of technology adoption and intensity of adoption. The application of each model depends on the objective of the research. Ermias (2013), Aman and Tewodros (2016) and Gairhe *et al*. (2017) used Tobit model and assume the two decisions (status and extent of technology adoption) are affected by the same set of factors. Akpan *et al*. (2012), Bayissa (2014), Hassen (2014) and Biru *et al*. (2016) used double hurdle model to analyze the status and intensity of technology adoption and assume the two decisions (status and extent of technology adoption) are affected by different set of factors. Victor (2016) used heckman two step model to analyze the status and intensity of technology adoption and assumed that there is sample selection bias.

It is assumed that farmers' decision in a given period of time and space are derived from maximization of expected utility or expected profit subject resource constraint. Therefore, adoption depends on farmers' discrete choice any technology from a mix including the traditional technology and a set of components of the new technology (Feder and Zilberman, 1985). To answer the question of what determines whether a particular technology is adopted

or not and intensity of adoption, most adoption of agriculture innovations studies using static rather than dynamic models (Bedru and Dagne, 2014).

2.4.1. Static adoption models

The static model refers to farmers' decision to adopt an improved technology at a specific place and 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. 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 and marketing the crop.

2.4.2. Dynamic adoption models

Dynamic models allow for changes in farmers' adoption decision as farmers gain skills in growing or marketing the improved seed from year to year. In 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 other variables as determined. At the end of each period, the actual yields, revenue and profit/losses realized, information and the experiences accumulated during the period by the farmer, and information from other farmers are used to update decision making in the next period. 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). Since farmers' decision on whether to adopt a new technology or not to adopt can be said to be of a binary nature (Baffoe-Asare *et al*., 2013), qualitative response regression models can best be used to analyze such decisions. Probit and logit regression models are preferred over the linear probability model when analyzing farmers' adoption decisions. This is because the linear probability model is very vulnerable to heteroskedasticity and therefore not able to fit the predicted values between 0 and 1, which gives way to unrealistic values (Stock and Watson, 2007). The two models are only different in the type of distribution used. The Probit model uses the standard normal distribution while the Logit model uses the standard logistic distribution.

Currently there are three alternative models to analyze adoption decision and intensity of adoption of agricultural technologies. These are Tobit, Heckman two stage procedure and Double Hurdle models. In principle, farmers adoption decisions and intensity of adoption can be analyzed jointly or separately (Berhanu and Swinton, 2003). If some observations have zero values for the quantity of improved variety applied, when observations are piled up at a censoring point, the standard Tobit model originally formulated by Tobin (1958) is appropriate model. Tobit model is an extension of the probit model and it is one approach to deal with the problem of censored data (Johnston and Dinardo, 1997). The Tobit model is used to analyze under the assumption that the same set of factors affect both the decision to adopt and intensity of adoption (Greene, 2003) and it assume that the decision to adopt and that of how much to adopt are made jointly. This suggests that factors influencing the two decisions are the same.

However, adoption and intensity of use decisions may not necessarily be made jointly. The decision to adopt may precede the decision on the intensity of use and the factors affecting each decision may be different (Greene, 1993). Thus, such decision situations can be analyzed using the two-part model called "double-hurdle" model (Cragg, 1971). Double hurdle model is used when factors influencing the decision to adopt the technology and the factors influencing the decision about the quantity of improved seed are different. Therefore, 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. 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 level of adoption of technology (Hassen *et al.*, 2012, and Hassen, 2014).

If there is sample selection bias Heckman two stage procedure model is another alternative. Heckman (1979) proposes a model that addresses the problem associated with sample selection bias. Heckman model is 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).

Cragg model can be as a flexible version of both the Tobit and Heckman model. The Tobit model assumes that the adoption decision and intensity of adoption decision can be modelled

as one equation whereas the Cragg model relaxes models both decision separately. In the Heckman model, zero observations arise due to non-adoption solely whereas the Cragg model allows zero Observations to arise in both the adoption decision and intensity of adoption. Therefore double-hurdle model is generally preferred when analyzing separately, factors affecting adoption and intensity of adoption. It is a combination of the probit and truncated regression models under the assumption of independence between the error terms. This study used double hurdle model to analyze adoption decision and intensity of use of improved potato varieties in the study area.

2.5. Empirical Studies of Agricultural Technology Adoption

A numerous studies made use of various methodologies to identify determinants of technology adoption in both developed and developing world. Mengistu *et al.* (2016) conducted study on determinant of adoption of potato production technology by smallholder farmers in Eastern Ethiopia using two-limit Tobit model. They found that variation in districts, access to irrigation, farm size, membership to cooperatives, annual income of the household significantly affected the adoption of potato technology package. In their study membership to cooperatives, annual income and access to irrigation positively and farm size negatively affected adoption of potato technology package.

Hassen (2014) applied double hurdle model to analyze factors affecting the adoption and intensity of use of improved forages in north east highlands of Ethiopia. The researcher found that positive effect of extension and credit service in enhancing the probability of adoption of improved forage technologies. In his study, the intensity of use of improved forage influenced by available labor, size of livestock ownership and farm size positively. Hassen *et al*. (2012) also found on the same model and in the same study area on determinant of chemical fertilizer technology adoption. Their empirical evidence indicated that extension and credit services, age, farm land size, education, livestock, off/non-farm income and gender positively affected the adoption of inorganic fertilizer.

Agajie *et al.* (2013) conducted study on adoption and impact of potato production technologies in Oromiya and Amhara regions. They found major problems that hindered further diffusion of

improved potato production technologies as lack of clean seed tubers, unaffordable prices of clean seed tubers, lack of sustainable demand for clean seed tubers, and low prices of ware potato. Inadequate awareness about technological packages, such as storage, chemical application, and others, also contributes to less diffusion.

A study done by Victor (2016), using Heckman two step model and endogenous switching probit model in Kenya, on adoption of Improved Sweet Potato Varieties (ISPVs) found that extension contact and education level positively and farming experience negatively influenced adoption of ISPVs. Yield variable, livestock number and group membership of farmers positively and household size and training contact negatively influenced the extent of adopting ISPVs. The author also found that the adoption of ISPVs had a robust and positive effect on farmer households' food security.

A study conducted by Gairhe *et al*. (2017) using Tobit model on determinants of improved potato varieties adoption in Nepal. Farmers' accesses to training and formal seed sources were important factor determining improved potato varietal adoption and positively influenced improved potato variety. However, households with larger farm size were less likely to allocate more area for improved potato varieties. Similarly, a pilot study was conducted by Bagheri (2015), using logistic regression model, on determinants of adoption of mini-tuber seed potato in Iran. Higher yield, healthy seeds, marketability and high quality of potato produced from mini-tuber seeds were the main important reasons of adoption. The author also investigated that adoption was positively affected by the extent of owned farmland size and extent of owned potato acreage. Among personal characteristics, education level, number of literate household members had positive effect while farmers' age and farming experience had negative effect on the adoption of mini- tuber seed potato, respectively.

A study conducted by Tewodros (2014) using univariete and bivariate analysis, on determinates of farmers adoption decisions of improved seed variety in Dabat District, North Gonder Ethiopia. The author found that demographic (sex, dependence ratio, education), land related (land holding, plot number, land fragmentation), income related (farm income and off-farm income), geographical (agro-ecology, plot distance) and farmers perceptions were statistically and significantly affected the adoption decision of improved seed variety. According to his

investigation plot number, livestock holding, farm and off farm income, extension service, access to credit and farmer's perception had positive effect on adoption of improved seed variety.

According to Akpan *et al.* (2012) using double hurdle model on fertilizer adoption and optimum use among farmers in southern Nigeria. The authors found that extension visit and farm output were positive and family size, farming size, number of goats and sheep have negative effect on fertilizer adoption and optimum use of fertilizer. According to them age, gender, farm size, purpose of crop production, perceived price of fertilizer, crop output, number of goats and sheep kept by respondents, and distance to fertilizer selling point were the main determinant factor that influence the decision to use optimum intensity of fertilizer by farming household heads. Among those variables age was positive and farm size, perceived high price of fertilizer, value of crop output, number of goats and sheep kept by respondent and decision to own poultry were negative determinants of optimum fertilizer use among farming household heads.

Study conducted by Biru and Lemma (2016) by using double hurdle model on analyzing the determinants of adoption of organic fertilizer by smallholder farmers in Shashemene district, Ethiopia. They investigated that household size negatively influenced decision to adopt organic fertilizer while livestock numbers, extension contacts, access to information media and membership to farmer based organizations positively influenced the decision to adopt organic fertilizer. Besides, farm size and membership to farmer groups influenced intensity of adoption positively while farm income and frequency of organic fertilizer application influenced use intensity of organic fertilizer negatively.

According to Aman and Tewodros (2016) using Tobit model on determinants of improved barley adoption intensity in Malga district of Sidama Zone, Ethiopia. The author found that age, farm experience, oxen, membership of cooperative, distance to all weather roads and annual income found to be significant variables affected the intensity of barley adoption.

Bayissa (2014) used double hurdle model to estimate the improved *teff* planting decision and intensity of use of households in Diga district of East Wollega Zone. The author found that sex of the household head, farming experience, participation on crop production training,

educational level, yield superiority and maturity period of new varieties were positively and significantly influenced both adoption and intensity of use of improved *teff.*

Ermias (2013) used Tobit model to analyze adoption of improved sorghum varieties and farmers' varietal trait preference in Kobo district, North Wolo Zone, Ethiopia. The researcher found that irrigated farm size, tropical livestock unit, striga infested farm size, farmers' perception on yield capacity and taste preference significantly and positively affected whereas 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 adoption of improved sorghum varieties.

Study conducted by Ghimire *et al.* (2015) using probit model on factors affecting adoption of improved rice varieties among rural farm households in central Nepal. They investigated that education, extension services and seed access, farm size, endowment of favorable land type, oxen influenced the probabilities of adoption of improved rice varieties.

Study conducted by Myrick (2016) used probit and tobit model to analyze the determinants of adoption and intensity of adoption of improved potato variety in the Yunnan province of China. The model results showed that household size affects both adoption and intensity of adoption of improved potato varieties positively and livestock wealth positively influenced adoption of improved potato variety. Similarly total farm size positively affected intensity of adoption of improved potato variety.

2.6. Conceptual Framework of the Study

Adoption decision and intensity of adoption of improved varieties are influenced by different factors. Factors such as personal, socio- economic, institutional and other factors determine the probability of adoption and intensity of use of improved potato varieties. However, based on the theoretical background and empirical adoption studies reviewed so far, the following conceptual framework is developed for this study. In the conceptual framework, the different factors are supposed to affect farmers' adoption decision and intensity of adoption of improved varieties. The framework shows relationship of the explanatory (independent) variables and the dependent variables.

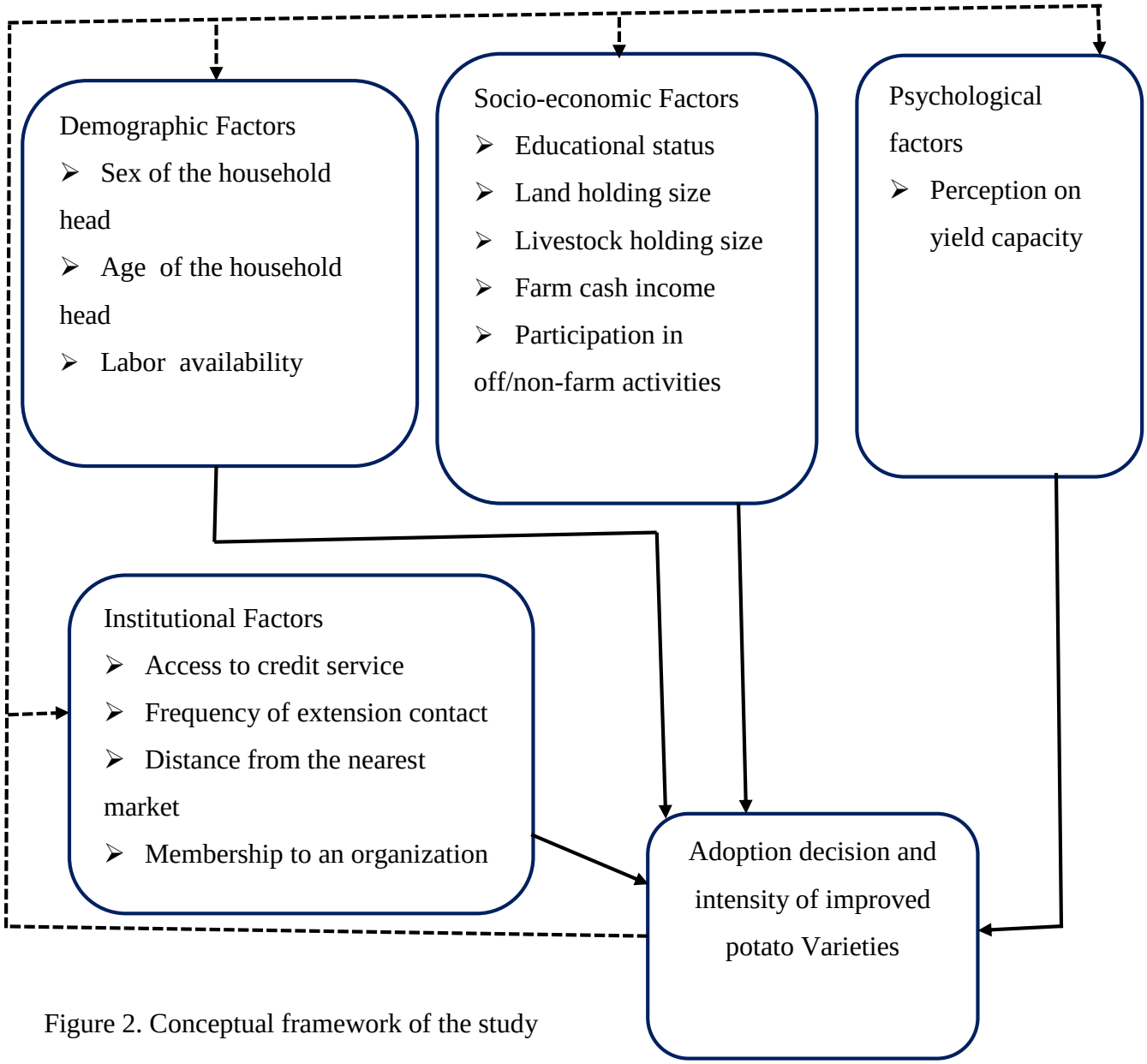

Figure 2. Conceptual framework of the study

Source: Own formulation

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

The study was conducted in Chilga *woreda*, which is found in North Gondar Zone of Amhara National Regional State (ANRS). Chilga is located at 63 km west of Gondar city and 230 km west of Bahir Dar the capital of Amhara National Regional State. Chilga is bordered on the south by Takusa, on the west by Metemma, on the north by Tach Armachiho, on the northeast by Lay Armachiho, and on the east by Dembiya. It is situated at an altitude ranging from 900 to 2250 m.a.s.l. (Kassahun, 2011).

According to Chilga *Woreda* Office of Agriculture and Rural Development (CWOARD) (2018), the total population of the *woreda* was about 237,581: of whom 120,103 were men and 117,478 were women. Among the total population of the *woreda* 20,745 or 9.37% are urban inhabitants while the remaining 90.63% live in rural areas. The *woreda* has 48 *kebeles* of which 41 are rural and 7 are urban *kebeles*. The *woreda* has Woinadega and Kola agro ecological Zones. The *woreda* has total area of 3,071.65 square kilometers and population density of 72.10 persons per square kilometer, which is greater than the Zone average of 63.76 persons per square kilometer. Among the total area of land 21.7 % is arable or cultivable, 1.9 is pasture, and 22.3% is forest or shrub-land, and the remaining 54.1% of land used for other purposes. A total of 47,336 households were counted in this *woreda*, resulting in an average of 4.68 persons to a household, and 45,352 housing units. The majority of the inhabitants (97 %) are Ethiopian Orthodox Christianity religion followers while 3% of the population are Muslim.

Agriculture is the major source of livelihood for the community in the *woreda*. Mixed farming, which includes crop and livestock production, is practiced in the area. *Teff*, sorghum, maize, potato, barley, wheat, ginger, sesame, cotton and garlic are the major crops grows in the *woreda*. Chilga *woreda* is selected as a study area which has high potential for potato production. All potato producing 16 *kebeles* are found in Woinadega agro ecological Zone.

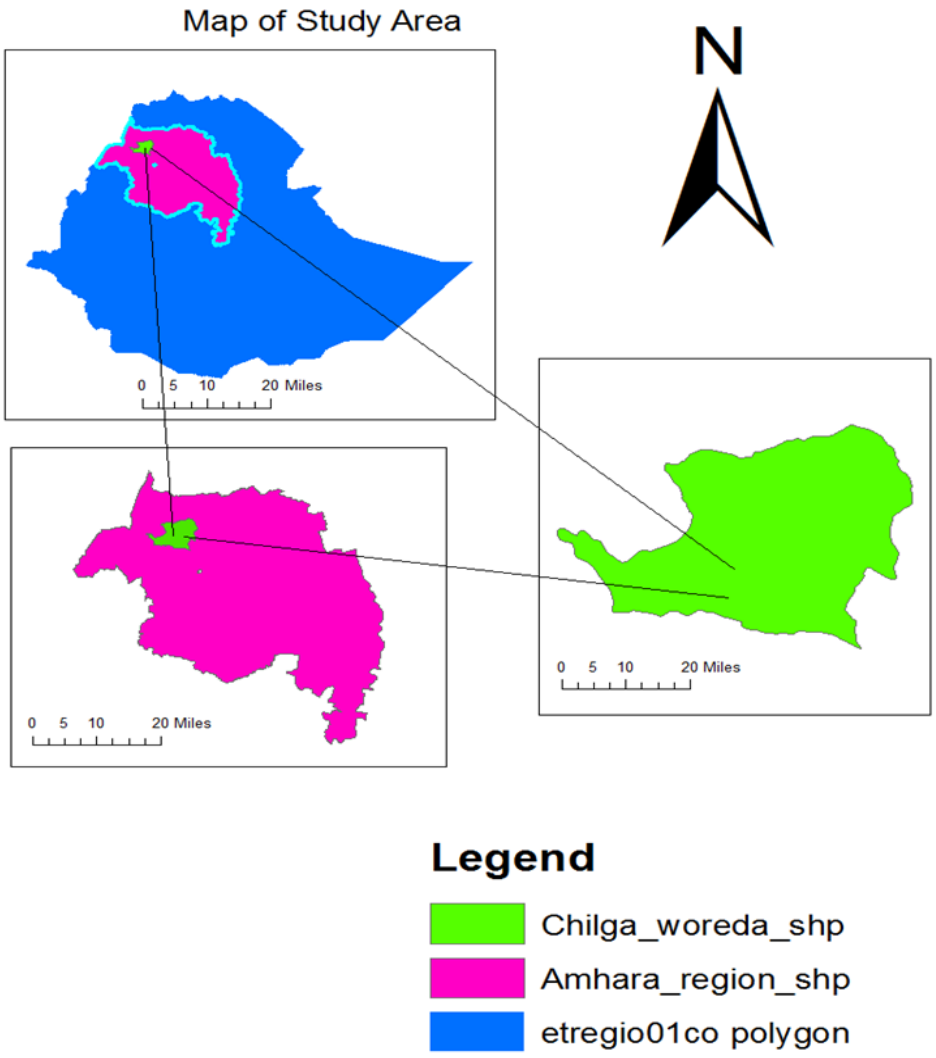

Figure 3. Location of the study area (Chilga *woreda)*

Source: Own sketch from GIS data (2018)

3.2. Data Types, Sources and Methods of Data Collection

In this study both primary and secondary data sources were used to collect qualitative and quantitative data. Primary data including demographic characteristics, socio- economic and institutional factors and other data relevant for meeting the objective of the study were generated from randomly selected farm households in the study area using structured questionnaire which was administered by trained enumerators. The questionnaire was designed and pre-tested in the field for its validity and content, and to make overall improvement of the

same and in line with the objectives of the study. While secondary data were collected from different published and unpublished` sources, such as government institutions, CWOARD, each *kebele* office, different published and unpublished reports and websites were used to generate relevant secondary data on adoption and intensity of adoption of improved potato varieties.

3.3. Sampling Procedures and Sample Size

A two stage random sampling techniques was used to select sample farm household heads. In the first stage, from 16 potato producing *kebeles* 4 sample *kebeles* were randomly selected. In the second stage from sampled potato producing *kebeles*, 160 potato producing household heads were randomly selected, using probabilities proportional to size sampling technique. Due to the heterogeneity of the population (adopters and non-adopters), the sample size was determined using Cochran (1963) formula.

$$n = \frac{z^2 pq}{e^2} \quad (1)$$

Where n is the sample size needed, Z (1.81) is the inverse of the standard cumulative distribution that corresponds to the level of confidence, e (0.07) is the desired level of precision, p (0.4) is the estimated proportion of an attribute that is present in the population and q (0.6)=1-p.

Table 1. Distribution of sample households in the sample *kebeles*

Sampled *Kebeles*	Total potato producer households(number)	Proportion sampled households (%)	Number of sample HH
Mirt Amba	1,013	34.87	56
Addis Alem	741	25.5	41
Anguava Buladgie	467	16.1	25
Tever Serako	684	23.53	38
Total	2,905	100	160

Source: CWOA and Own computation, 2018

3.4. Method of Data Analysis

Both descriptive statistics and econometric model were used to analyze the data for this study.

3.4.1. Descriptive statistics

Descriptive statistics was employed for the description of different demographic, socio-economic and institutional characteristics of adopters and non-adopters of the sample respondents. These are mean, percentage, standard deviation, frequencies, minimum and maximum values were used to analyze the household's characteristics. In addition, inferential statistics such as t- test and chi-square test were used. T-test for continuous variables chi-square for dummy variables were used to see whether there is significant mean/ percentage difference between adopters and non-adopters in terms of different demographic, socio economic, institutional and psychological factors.

3.4.2. Econometric model

In this study, double-hurdle model was used since it allows for the distinction between the determinants of adoption and the intensity of improved potato varieties through two separate stages. In the double hurdle model two stage estimation was involved. In the first stage probit model was used to determine factors affecting adoption decision of improved potato varieties. The second stage of double hurdle model was truncated regression model which is used to analyze factors determining the intensity of improved potato varieties in the study area.

Model specification: In the first stage of double hurdle model**,** Probit model takes a value 1 and 0 that are assigned to represent the choice whether a farmer decides to use improved potato varieties or not. The probit model that assesses the household improved potato varieties adoption and following Hassen *et al*. (2012), the model has an adoption (D) decision with an equation:

$D_i = 1 \ldots if \ldots . D_{i^*} > 0 \ldots . . and$

$D_i = 0 \ldots if \ldots . D_{i^*} \leq 0$

$\mathrm{D_{i^*}} = \alpha' \mathrm{Z_i} + U_i$ (2)

Where D_{i^*} is a latent (unobserved) variable describing household's decision of whether or not to adopt improved potato varieties that takes the value 1 if a farmer adopts the technology and 0 otherwise: D_i is the observed variable represents the households adoption decision. Z is a

vector of explanatory variables and α is also a vector of parameters. The intensity of adoption (Y) decision equation is also given as:

$$Y_i = Y_{i^*} \ldots \text{if} \ldots Y_{i^*} > 0 \text{ and } D_{i^*} > 0$$
$$Y_i = 0 \ldots \text{otherwise}$$
$$Y_{i^*} = \beta' X_i + V_i \quad (3)$$

Where Y_{i^*} is latent variable describing intensity of improved potato varieties. Y_i is the area of improved potato varieties in hectare signifying intensity of adoption ; X_i is the vector of explanatory variables affecting the intensity of used; β is the vector of parameter to be estimated. The log-likelihood (LL) function for the double-hurdle model is given as;

$$\log L = \sum_0 \ln[1 - \emptyset(\alpha Z_{i'})(\frac{\beta X_{i'}}{\sigma})] + \sum_+ \ln[\emptyset(\alpha Z_{i'})\frac{1}{\sigma}\varphi(\frac{Y_i - \beta X_{i'}}{\sigma})]$$

$$Y_{i'} = \beta' X_i + V_i \quad (4)$$

The zero (0) means summation over the zero observations and the positive (+) sign also means summation over the positive observations. $\emptyset(.)$ is the standard normal cumulative distribution functions and $\varphi(.)$ is also the probability distribution functions. The error terms U_i and V_i are assumed to be independent.

3.4.3. Test for model appropriateness: Double-hurdle versus Tobit model

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

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

Where Γ =likelihood ratio statistic 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 both 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 $\Gamma > \chi_k^2$.

For good measure, Akakie's Information Criterion (Akakie, 1974) is also included as a model selection criterion. The Akakie's information criteria (AIC), serving as a measure of goodness of fit and model selection is generally defined, for individual models by:

$$AIC = 2K - 2 \ln (L) \quad (6)$$

Where, k = number of parameters in the model, L= the likelihood function

The AIC method helps to know that the specified model best explains the data and the preferred model is the one with the lowest AIC value, compared to its alternative model (Hailemariam *et al.*, 2006; Adam, 2010).

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. 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:

$$\text{VIF (xi)} = \frac{1}{1 - R_i^2} \quad (7)$$

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).

3.5. Definition of Variables and Working Hypothesis

3.5.1. Dependent variables

A. Adoption decision

It is a binary dependent variable indicating the adoption decision of improved potato varieties by a sample household in a given cropping area. The dependent variable is the binary choice variable which is 1 if the household used the improved potato varieties and 0 otherwise.

B. Adoption intensity

Adoption intensity is continuous variable measured in percentage. It refers to the proportion of area allocated to the improved potato varieties divided by the total area of land covered by potato in 2017/2018 production year.

$$\text{Adoption intensity} = \frac{\text{Area allocated to improved potato variety}}{\text{Total area allocated to potato by each farmer}} \times 100 \quad (8)$$

3.5.2. Independent variables

The independent variables of the study were those which are hypothesized to have an association with adoption decision and intensity of improved potato varieties. The findings of past studies on household heads of adoption, the existing theoretical explanations and the researcher's preliminary knowledge of the farming systems of farmers in the study area was used to select explanatory variables for hypotheses.

Sex of the household head (SEXHH): It is a dummy variable (1 if male, and 0 otherwise). Sex is one of the factors expected to influence adoption of new technologies. Due to many socio-cultural values and norms, males have freedom of mobility and participation in different meetings and consequently have greater access to information (Almaz, 2008; Hassen, 2014).

Therefore being male headed household is expected effect adoption and intensity of adoption of improved potato variety positively.

Age of the household head (AGE): It is continuous variable measured in number of years at the time of survey. As the age of the household head increases, the probability of adoption decreases. Because, with age, a farmer can become more risk averse and then tend to be reluctant to new technologies (Aklilu, 2006 and Bagheri, 2015). On the other hand older farmers may have more farming experience and better access to new technologies than younger farmers. Older farmers might have gained knowledge (Hassen, 2014). Hence, in this study age was expected to affect probability and intensity of adoption positively or negatively.

Education status (EDUC): This is a categorical variable measured in level of grades in the household that includes a person who can read and write and others. It takes 0 for illiterate household heads, 1 can read and write, 2 attend primary education and 3 attend secondary education and above. It increases the farmer's ability to obtain; process and use information relevant to the adoption of improved technologies. Chilot and Dawit (2016) found that education is a human capital often considered as the best alternative of empowering farm households and it improves access to information on improved technologies. Chiputwa *et al.* (2011) in their study found out that education level positively correlated with adoption and intensity of use of crop rotation. Therefore, education level was expected to affect adoption and intensity of adoption of improved potato seed varieties positively.

Land holding size (LANDHOLD): Land holding size is area of land owned by a household measured in hectare. Farmers who own and cultivate larger farms are likely to use improved crop varieties and allocate larger areas to improved maize varieties (Chilot and Dawit, 2016). Farmers who have relatively large size will be more initiated to adopt improved technologies (Almaz, 2008) and Myrick (2016) found that total farm size positively and significantly affected the intensity of use of technology. Therefore, in this study land holding size was expected to affect adoption and intensity of adoption of improved potato varieties positively.

Access to credit (CREDITACC): It is a dummy variable, which takes a value of 1 if the farm households have used credit or 0 otherwise and measured in terms of whether respondents have availed any form of credit for agricultural purposes. Farmers who have access to credit may

overcome their financial constraints and therefore buy planting materials and agricultural inputs. Farmers without cash and no access to credit can find it very difficult to attain and adopt new technologies (Mulugeta, 2000).Hassen *et al*. (2012) found that access to credit influenced adoption and intensity of use of agricultural technologies positively. Therefore, in this study credit access was hypothesized to affect adoption and intensity of improved potato varieties positively.

Frequency of extension contact (FRECON): This refers to the number of contacts that the respondent made with extension agents and it is a continuous variable which indicates number of days the households visited by extension agents with during the survey year. Extension services refers to advice, training, demonstration and distribution of farm inputs. The effort to disseminate new agricultural technologies is within the field of communication between the change agent (extension agent) and the farmers at the grass root level. Here, the frequency of contact between the extension agent and the farmers is hypothesized to be the potential force which accelerates the effective dissemination of adequate agricultural information to the farmers, thereby enhancing farmers' decision to adopt new technologies. Mignouna *et al.* (2011), Hassen (2014) and Victor (2016) explained that access to extension services enhanced farmers' exposure and familiarity to agricultural technologies. Hence, in this study extension contact was expected to affect adoption and intensity of adoption of improved potato seed variety positively.

Labor availability (LABORAV): It is a continuous variable measured in adult equivalent with the availability of active and productive family labor in the household. A larger household size has the capacity to relax the labor constraints required during introduction of new technology (Mignouna *et al*., 2011, Chilot and Dawit, 2016). 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. According to Hassen (2014) adoption affected positively by family labor availability. Therefore, labor availability was expected to affect adoption and intensity of adoption of improved potato varieties positively.

Farm cash income (FARMINC): The farm cash income refers to the total annual earnings of the family from sale of agricultural product such as sale of crop, livestock and livestock product after meeting family requirements. This is believed to be the main source of capital for purchasing agricultural inputs. The higher the household's cash income, the higher the probability of acquiring farm inputs leading to higher adoption of new technologies. Yishak *et al.* (2011) found positive influence of household's farm income on adoption of improved technologies. Thus, those households with a relatively higher level of farm income are likely to purchase improved potato seed or other essential agricultural inputs. Farmers with higher annual income are found to be better adopters of potato technology package as compared to those with lower annual income levels (Mengistu *et al.,* 2016).Therefore, the variable was hypothesized to influence probability of adoption and intensity of adoption of improved potato varieties positively.

Participation in off/non-farm activities (POFFNON): It is a dummy variable taking 1 if a household head participated in off/non-farm income generating activities and 0 otherwise. Activities include petty trading, sale of trees for construction of house, sell of hops (*gesho*) for preparation of tela, guarding activity, charcoal selling, firewood selling and participation for non-farm jobs. Martey *et al*. (2013) in their study found that off-farm income affect adoption and intensity of adoption positively. Households with relatively higher off/non-farm activities are expected to better adopt improved technologies. Hanschuch and Wollni (2013) found in their study that off-farm income affected adoption of agricultural technologies positively. The expected effect of this variable on adoption and intensity of adoption of improved potato seed variety was positive.

Distance to nearest market (DISMARKT): It is a continuous variable measured in kilometers. The longer the distance of farmers' residence from the nearest market, the more difficult 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 farmer to the market, the more likely he/she receive valuable information, buy farm inputs and sale his/ her farm produces easily, and hence more likely to adopt improved technologies and transaction cost decreases. Bayissa (2014) found that distance to market center has a negative and significant relationship with probability of adoption and intensity use of improved teff varieties. The

expected effect of this variable was negative on adoption and intensity of adoption of improved potato varieties.

Livestock holding size (LVSTOCK): This is the total number of livestock holding by the farm household measured in tropical livestock unit. Livestock are important sources of income, which can enhance the purchasing power of improved potato seed and other agricultural inputs. Livestock ownership is expected to be positively related to adoption of technologies because it serves as proxy for wealth status (Hassen, 2014,). Victor (2016), Myrick (2016) found that a positive association between adoption and intensity of adoption with livestock ownership because livestock may serve as a proxy for the availability of manure. Hence, livestock holding is expected to affect adoption and intensity of adoption of improved potato varieties positively.

Membership to institution/ organization (MEMORG): it is a dummy variable represented by 1 if a household is the member of farmers' organization and 0 otherwise. Membership to an organization is important for information exchange and experience sharing among farm households on the use of improved agricultural technologies (Aman and Tewodros, 2016). Hence membership to an organization was expected to affect adoption and intensity of use of improved potato varieties positively.

Perception on yield capacity (PERYIELD): it is a dummy variable, representing 1 superiority of improved potato variety over local variety in terms of yield, 0 otherwise. Farmers' perception on new varieties is important to adopt that new variety. Bayissa (2014) found that perception on yield capacity positively and significantly affected the adoption decision and intensity of use of improved *teff* technologies. Therefore perception on yield capacity was hypothesized to affect adoption and intensity of improved potato varieties adoption positively.

Summary of variables and expected outcome

Table 2. The independent variables and expected signs

Variable	Definition	Type	Measurement	Expected sign
Dependent				
ADD	Adoption decision	Dummy	1= adopter 0= non-adopter	
ADI	Intensity of adoption	Continuous	Percentage	
Independent				
SEXHH	Sex of the household head	Dummy	0= female 1=male	+
AGE	Age of the household head	Continuous	Number of years	+/-
EDUC	Education status	Categorical	0=Illiterate, 1=read and write 2= primary(1-8),3 secondary and above (9 and above)	+
LANDHOLD	Land holding size	Continuous	Hectare	+
CREDITACC	Access to credit	Dummy	1= access to credit 0= otherwise	+
FRECONEA	Frequency of contact with extension agent(s)	Continuous	Number	+
LABORAV	Labor availability	Continuous	adult equivalent	+
FARMINCO	Annual farm income	Continuous	ETB	+
POFFNON	Participation in off/non-farm activities	Dummy	1= participated off/non-farm 0= otherwise	+
LVSTOCK	Livestock holding size	Continuous	Tropical livestock unit	+
DISMARKT	Distance to nearest market	Continuous	Kilometer	_
MEMORG	Membership to institution/ organization	Dummy	1= member 0= otherwise	+
PERYIELD	Perception of yield capacity	Dummy	1=improved superior than local, 0= not superior	+

4. RESULTS AND DISCUSSION

This chapter contains overall findings of descriptive and econometric analysis results and discussions and it is categorized in three sections. The first section provides descriptive analysis of both adopters and non-adopters. The second section presents results on status of potato production. While, in the third section the econometric analysis results from double-hurdle model are presented and discussed.

4.1. Descriptive Statistics

In this section demographic, socio economic, institutional and psychological characteristics of sample households such as sex, age, education status, labor availability, land holding size, farm cash income, participation in off/non-farm activities, livestock holding in TLU, access to credit, frequency of extension contact, distance from the nearest market, and the like are discussed and presented.. Adoption status and intensity of improved potato varieties adoption and perceptions toward improved potato varieties attributes were also discussed.

4.1.1. Descriptive statistics for categorical explanatory variables

Sex of the household head: In this study, out of the total 160 sample households 88.1% were male headed households and the rest 11.9% were female headed households. The proportion of male-headed households was 89.4% for adopters and 86.7% for non-adopters. The result of Chi-square indicated absence of significant difference between adopters and non-adopters in terms of sex of household head (Table 3).

Educational status of the household head: Education is considered to increase farmer's ability to obtain, process and use information relevant to the adoption of improved crop varieties. As shown in Table 3, out of 160 sample households, about 43.8% of sample households were illiterate, 23.1% can read and write, about 28.1% attended primary education (grades 1-8) and 5 % of sample households attended secondary school education and above (grades 9 and above). Among the adopters 27.0% were illiterate, 25.9% can read and write, 41.2% attended primary education and remaining 5.9 % attended education level of secondary and above. From non-adopters about 62.7 % were illiterate, 20 % can read and write, 13.3 %

attended primary school and the remaining 4% attended secondary school and above. The result of the study indicated that the percentage difference between adopters and non-adopters with respect to education level was statistically significant at 1% probability level.

Participation in off/non-farm activities: The adoption of technologies is related with the income of the users of technologies. As households participated in off/non-farm activities, they can gain more income and they can have better purchasing power of agricultural inputs. The survey result in Table 3 indicated that 55.6% of sample household heads were participated in off/non-farm activities and the remaining 44.4% were not participated. Out of the total sample households 75 % of adopters and 33% of non-adopters participated in off/non-farm activities. The percentage difference among adoption categories in terms of this variable was statistically significant at the 1% level of significance.

Membership to institution/organizations: Out of the total sample households about 43 % households were member of the organization while 57% of them were not member of the organization. The survey result indicated that 55.3 % of adopters and 28% of non-adopters were member of the organization like farmers' associations/cooperatives, *ikub* and *idir*, and credit and saving. The chi- square result indicated significance difference between the two groups in terms of membership to institutions/ organization at the 1 % significant level.

Access to credit: Credit service is an important source of income inputs for agricultural production and to adopt new technologies especially for the poor farmers. According to the result presented in Table 3, out of the total sample households about 55.6% had access to credit whereas 44.4% had not access to credit due to lack of collateral, high interest rate, less capacity to repay the loan, and some farmer did not need credit use. Proportionally 58.8% of adopters and 52% of non-adopter sample households received credit. Credit and saving institutions and micro finance institutions are the main credit provider institutions in the study area. The difference between adopters and non-adopters with respect to access to credit was found statically insignificant.

Table 3. Descriptive statistics for categorical explanatory variables

		Adopters		Non-adopters		Total		
Variables		N	%	N	%	N	%	χ^2
Sex of the household head	Male	76	89.4	65	86.7	141	88.1	0.29
	Female	9	10.6	10	13.3	19	11.9	
Educational status of the household head	Illiterate	23	27.0	47	62.7	70	43.8	23.41***
	Read and write	22	25.9	15	20	37	23.1	
	Primary	35	41.2	10	13.3	45	28.1	
	Secondary and above	5	5.9	3	4	8	5.0	
Participation in off/non-farm activities	Yes	64	75.3	25	33	89	55.6	28.42***
	No	21	24.7	50	67	71	44.4	
Membership in institutions/organizations	Yes	47	55.3	21	28	68	43	12.15***
	No	38	44.7	54	72	92	57	
Credit access	Yes	50	58.8	39	52	89	55.6	0.75
	No	35	41.2	36	48	71	44.4	

Note: "***" denote the level of significance at 1%.
Source: Own survey results, 2018.

4.1.2. Descriptive statistics for continuous explanatory variables

Age of the household head: The mean age of the sample households was 43.7 with the standard deviation of 11.1. The average age of sample households showed that adopters of the sample households had average age of 43.1 with standard deviation 11.1 and non-adopters had average age 44.4 with standard deviation 11.1. In Table 4, the t-test result showed absence of significance mean difference between adopters and non-adopters in terms of age of the households.

Labor availability: As indicated in Table 4, below the average labor availability of the sample households were 4.2 in adult equivalent with standard deviation of 1.6. The average labor availability of adopters and non-adopters were 4.4 and 4 with standard deviation of 1.6 and 1.4 respectively. The study showed significant mean difference in labor availability between adopters and non-adopters at the 10% significance level.

Land holding size: Five land arrangements practiced in the study area. Namely own land, rented in land, rented out land, shared in land and shared out land. Table 4 below, shows that the average land holding of sample households was 1.9 ha with standard deviation of 0.9. The average land holding size of adopters and non-adopters was 2 ha and 1.7 ha with standard deviation of 0.8 and 1.0 respectively. The t- test result showed that mean difference of land holding size between two groups was statistically significant at 10% significance level.

Annual cash income from farm: Farm income refers to the total annual earnings of the households from sales of agricultural produce after meeting their family requirements. This is assumed to be the main source of capital for purchasing improved seed and other essential agricultural inputs. Table 4, below depicts that the average annual farm cash income of 8521.2 ETB with standard deviation of 5470.3. The average annual cash income from farm of adopters and non-adopters was 8312.6 ETB and 8304 ETB with standard deviation of 4983 and 6001**.**6 respectively. The t- test result revealed that absence of significance mean difference among the two categories with respect to this variable.

Livestock holding size: Livestock is one of the major assets for the farmers and also indicates farmer's level of wealth in the study area. Livestock production plays an important role both in crop production and as cash in the study area. Types of livestock owned by households are oxen, cows, heifers, calves, horses, donkey, sheep, goat and poultry. Livestock provides traction, manure, and is a source of cash that can be used to purchase goods for household consumption and production inputs. As indicates in Table 4, the average livestock holding of sample households was 3.1 TLU with standard deviation of 1.6. Adopters had more own livestock (3.5 TLU with standard deviation 1.5) than non-adopters (2.6 TLU with standard deviation of 1.5). This study showed that mean difference among adoption categories related to livestock holding was statistically significant at 1% significance level.

Frequency of extension contact: Extension services usually play major role in disseminating new and improved farming techniques. It enables farmers to be aware of the benefit of new technologies. The survey result in Table 4, shows that sample households average extension contact per year was 3.8 with standard deviation 1.4. The adopters' average extension contact per year was 4.6 with standard deviation of 1.2 whereas the average extension contact of non-

adopters was 3 with standard deviation of 1.2. This result showed that adopter sample households had more extension contact than non-adopter sample households. The t-test result revealed that the mean difference of frequency of extension contact between adopters and non-adopters was found to be significant at the 1% probability level.

Distance to the nearest market: As indicated in Table 4, the average distance of sample respondents' home from the nearest market place was found to be 5.4 km with standard deviation of 4.2**.** On average adopters are located 4.3 km with standard deviation of 3.6 and non-adopters are located 6.7 km away on average from the nearest place with standard deviation of 4.4. The t-test result showed that the mean difference in distance from market between adopters and non-adopters was found to be significant at 1% probability level.

Table 4. Descriptive statistics for continuous explanatory variables

	Adopters (n=85)		Non-adopters (n=75)		Total sample(n=160)		
Variables	Mean	Std.dev	Mean	Std.dev	Mean	Std.dev	t –value
Age of the household	43.1	11.1	44.4	11.1	43.7	11.1	0.72
Labor availability	4.4	1.6	4	1.4	4.2	1.6	-1.74*
Land holding size	2.0	0.8	1.7	1.0	1.9	0.9	-1.7 *
Annual farm income	8312.6	4983	8304	6001.7	8521.2	5470.3	-0.47
Livestock holding	3.5	1.5	2.6	1.5	3.1	1.6	-3.73***
Frequency of contact	4.6	1.2	3	1.2	3.8	1.4	-8.48***
Distance to the nearest market	4.3	3.6	6.7	4.4	5.4	4.2	3.84***

Note: "***"and "*" represents the level of significance at 1% and 10% respectively.
Source: own survey results, 2018.

4.1.3. Farmers' Perception on Improved potato Variety Attributes

Farmers' perception on a given technology is assumed to determine farmers' decision to adopt and the intensity of use of that technology. The perception was tested based on different potato varietal attribute preferences of sample households. These attributes include farmers' perception on improved potato variety with respect to yield capacity, disease resistance, drought resistance, perishability resistance and the like.

As summaries in Table 5, out of the total sample households 65% of the sample respondents perceived that improved potato varieties give higher yield advantage than local varieties. About

84.7% of adopters reported that improved potato varieties being higher in their yielding capacity than local potato varieties. Even if 15.3% of adopters perceived improved potato varieties not better than local varieties in terms of yield, they adopt improved potato varieties because of improved potato varieties are better than local varities in terms of the ability to resist the diseases, maturity period, tests and the ability to resist drought in the study area. However only 42.7% of non-adopters perceived that improved potato varieties being superior in their yield advantage compared with local varieties. The chi-square test showed that the difference in perception of yield difference between adopters and non-adopters was statistically significant at 1% probability level.

Farmers' perception on disease resistance of improved potato varieties was also another comparison criterion that farmers used to value the advantage of improved potato varieties in the study area. From the total sample households 59.4% of them perceived that improved potato variety better than local variety in terms of disease resistance. Proportionally 67.1% of adopters and 50.7% of non-adopters perceived that improved potato varieties being better than local varieties in terms of disease resistance capacity. The chi-square showed difference between the two groups in terms of perception on disease resistance capacity of improved potato variety at 5% significance level.

In terms of drought resistance about 54.4% of sample households reported that improved potato variety being more drought resistant than local variety. On the other hand 45.6% of the respondents reported that improved potato varieties being less drought resistant than local varieties. About 57.7% of adopters and 50.7% of non-adopters perceived that improved potato variety more drought resistance than local variety. There was no significant percentage difference in perception between the groups in terms of drought resistance of improved varieties. Finally respondents were asked about perishability resistance of improved potato variety as compared to local variety.

Accordingly, 61.3% of sample respondents reported that improved potato varieties being more perishability resistant than local varieties of which 69.4% of the adopters and 5% of the non-adopters perceived that improved varieties are better than local varieties in terms of perishability resistant. While 30.6% of adopters and 48 % of non-adopters perceived that

improved potato varieties less perishability resistance than local variety. In Table 5 below, the chi-square test showed significant difference in perception of perishability resistance of improved potato variety between the two categories at 1% significance level.

Table 5. Perception of sample respondents about improved potato variety attributes

Attributes		Adopters		Non-adopters		Total		χ 2-value
		N	%	N	%	N	%	
Better yield	Yes	72	84.7	32	42.7	104	65	30.95***
	No	13	15.3	43	57.3	56	35	
Disease resistance	Yes	57	67.1	38	50.7	87	59.4	4.44**
	No	28	32.9	37	49.3	73	40.6	
Drought resistance	Yes	49	57.7	38	50.7	87	54.4	0.78
	No	36	42.4	37	49.3	73	45.6	
Perishability resistance	Yes	59	69.4	39	52	98	61.3	5.089**
	No	26	30.6	36	48	62	38.8	

Note "***"and "**"represents the level of significance at 1% and 5% respectively.
Source: own survey result, 2018.

4.2. Adoption Status and Source of Improved Potato Seeds

Chilga *woreda* is known for potato production from North Gonder Zone. Potato is used for consumption (especially in the food shortage months of July and August because of its early maturity) and marketing in the study area. Almost all sampled potato producing households produce potato through rain-fed. Both local and improved varieties were used for potato production in the study area. Improved potato varieties growing in the study area were Belete, Jalenie and Gudenie varieties whereas from local varieties *Shewie, America, key Abeba* and *Nech Abeba* varieties. The analysis of adoption of sample households showed that from the total of 160 sample farm households 85 (53%) used improved variety whereas 75(47%) did not use improved varieties. The result indicated that out of the total adopters 61(71.8%) planted Belete which was the most widely adopted and productive variety, 14(16.4%) used Jalane and 10(11.8%) were used Gudene varieties.

Table 6. Potato varieties adopted by sample households

Variety	Growers	
	N	%
Belete	61	71.8
Jalane	14	16.4
Gudene	10	11.8
Total	85	100

Source: own survey results, 2018

In this study, the intensity of adoption measures the depth or extent of adoption expressed in terms of area of land allocated to improved potato varieties. The proportion of area allocated for improved potato varieties (intensity) among adopter households was 63.8%. An average of 0.15 ha and 0.10 ha allocated for improved and local varieties respectively.

Table 7. Area allocated for local and improved potato varieties

	Local	Improved
	Area(ha)	Area(ha
Mean	0.10	0.15
SD	0.06	0.05
Maximum	0.25	0.25
Minimum	0.06	0.06

Source: own survey result, 2018

Both organic (compost and farm yard manure) and inorganic fertilizers (DAP and Urea) inputs were used for potato production in the study area. Out of the total sample households about 90% of them used organic fertilizer (11.9% of respondents used farm yard manure, 17% used compost and 61.1% of them used both farm yard manure and compost) and 10% of the respondents did not use organic fertilizers in the study area. All potato producing sample household heads used DAP and Urea for better production.

During the survey time sample households heads reported that the major opportunities for potato production in the study area were availability of demand for potato production, good weather condition, accessibility of credit service and good infrastructure. Whereas the major potato production constraints are shortage of land, poor fertility of land, poor input supply (IPV, DAP, Urea, chemicals), lack of modern storage, natural factor (shortage of rain), perishability nature of potato, lack of irrigation were the major production constraints raised by respondents

during the survey time. About 97 % of the sample households used traditional storage system. Non-availability of seed of required variety, high seed price, and low seed quality, non-recyclability of improved potato seeds because of lack of modern storage and lack of sustainable seed were also identified by sample households as major constraints in purchasing potato seed in the study area.

Generally, according to respondents the major problems that hindered from using and further diffusion of this technology are high seed price for quality seeds, disease and pest problems, unavailability of quality seeds at the right time (supply shortage) and financial constraints.

The survey result attests that the source of potato seeds are own recycled potato seeds from previous growing seasons (stock), local market, *woreda* office of agriculture, specialized seed growers and neighbor farmers. Own recycled seeds from previous growing seasons and local markets shared the greater amount of potato seed planted by the sample farmers. Farmers select and store small tubers from their own production to plant it in the next season. Seeds from *woreda* office of agriculture was reported as more quality than other sources.

4.3. Econometric model results

In this study double hurdle model was used to identify the influence of demographic, socio economic, institutional and psychological factors that determine adoption decision and intensity of improved potato varieties. The selection of the model was based on the assumption of independence between adoption decision and intensity of adoption of improved potato varieties and normal distribution of error terms.

There are two independent decisions in double hurdle model. In the first stage probit model was used to identify factors affecting adoption decision of improved potato varieties. In the second stage truncated regression model was used to identify factors that determine intensity of improved potato varieties adoption in the study area.

Prior to running the double hurdle model, the existence of multicolleniarity problem has been checked using variance inflation factor (VIF). Accordingly there was no serious problem of multicollinearity among the explanatory variables. Table 1 in the appendix part shows the

highest VIF value is 1.41 which is below the maximum value of 10 (VIF) and as a rule of thumb for the existence of multicollinearity. Therefore, based on the above tests all the hypothesized explanatory variables were included in the respective models for further analysis.

The double-hurdle model was tested against the Heckman model. Moreover, the result from the Heckman two-step procedure suggests that there is no sample selectivity bias because the inverse mills ratio (IMR) (0.846) is statistically insignificant. This suggested the adoption decision equation and the intensity equation can separately be estimated by a probit and truncated regressions, respectively.

An empirical test of double hurdle versus Tobit model was used to choose the best model by using both log likelihood test and Akaki Information Criteria (AIC). Joint decision criteria of log likelihood and AIC test indicates that the rejection of Tobit model and acceptance of double hurdle model. The test result in Appendix Table 4 revealed that the calculated statistical value of likelihood ratio (183.28) which is greater than the tabulated or critical value of $\chi 2$ (13) = (27.7) at 1% level of significance. The AIC for the double hurdle model (46.94) was lower than that of Tobit model (230.22).This is an indication of the existence of two separate decision-making stages in which individuals make independent decisions regarding the adoption decision and intensity of adoption of improved potato varieties.

4.3.1. Determinants of adoption decision of improved potato varieties

In this section the first hurdle of double hurdle model which is probit model was used to determine adoption decision of improved potato varieties. The dependent variable for the probit model is adoption decision of improved potato varieties. A total of thirteen variables of which six categorical and seven continuous explanatory variables were included in the model. From the total explanatory variables seven variables significantly affected the adoption decision of improved potato varieties. These are educational status of the household head, land holding size, livestock holding size, participation in off/non-farm activities, frequency of extension contact, membership to institutions/organizations and perception on yield capacity. The marginal effects of the first hurdle indicated how a given variable affects the likelihood/probability of adoption of improved potato varieties. The chi-square test indicates

that the overall goodness-of-fit of the probit model was statistically significant at 1% probability level. Detail of significant variables are presented as follows.

Educational status of the households: Educational status of the household head positively and significantly influenced adoption of improved potato varieties at the 5% significance level. Keeping other variables constant, as farmers get educated the probability of adoption of improved potato varieties would increase by 18%. This implies that educated farmers being more likely to adopt improved potato varieties than those who are not educated in the study area. The reason may be educated farmers may have relatively more access to information and become aware to new technology and this awareness may enhances the adoption of improved potato varieties than illiterate farmers. This is consistent with the results of Abebe *et al*. (2013), Teklemariam (2014) and Bagheri (2015).

Land holding size: The model result showed positive and significant relationship between land holding size and probability of adoption of improved varieties at the 1% significance level. Other variables held constant, an increase in total land holding by 1 ha would result in an increase in the probability of adoption of improved potato varieties by 15.8%. This result showed that farmers who have relatively more land holding are more likely to adopt improved potato varieties than farmers who have smaller land holding size. This result is consistent with the findings of Chilot and Dawit (2016).

Participation in off/ non-farm activities: Participation in off/non-farm income generating activities significantly and positively affected adoption decision of improved potato varieties at the 10% significant level. Keeping other variables constant, involvement of household heads in off/non-farm income generating activities would increase the adoption decision of improved potato varieties by 19.7%. The possible reason may be farmers who participated in off/ non-farm activities, they get more income which is used for purchasing improved potato seed and other inputs and they are more likely to adopt improved potato varieties compared to farmers who are not participated in off/non-farm income generating activities. The result is consistent with Martey *et al*. (2013) and, Hanschuch and Wollni (2013).

Livestock holding size (TLU): Livestock ownership in TLU positively and significantly influenced the probability of adoption of improved potato varieties at 10% significant level. Other factors kept constant, a unit increase in livestock ownership in TLU increases the probability of adoption of improved potato varieties by 7.3%. This may be farmers who had relatively large livestock might have more asset and which is source of income that can be used to purchase improved seed and other agricultural inputs and more likely to adopt improved potato varieties as compared to farmers who own relatively less livestock. In addition to this they can have more livestock products (farm yard manure) which is important organic fertilizer for potato production. In general the result indicated farmers with more livestock ownership more adopted an improved potato variety production. The study is consistent with Berihun *et al*. (2014), Tewodros (2014), and Myrick (2016).

Frequency of extension contact: Frequency of extension contact positively and significantly affected adoption of improved potato varieties at 1% probability level. Other variables held constant, for each additional one day contact with extension agent, the probability of adoption of improved potato varieties of farmers will increase by 24.6%. The result indicated that farmers who have more contact with extension agent having more probability of adopting this technology compared to those who have less contact. The possible reason for this might be farmer's frequent contact with extension agent can provide access to information about improved potato variety technology and build their knowledge for using this technology. This result is consistent with Mignouna *et al.* (2011), Teklemariam (2014), and Victor (2016).

Membership to institutions/organizations: Membership to an institution/organization had positive and significant influence on adoption of improved potato varieties at 1% significance level. Keeping other variables constant, being member of an institution /organization increased the probability of adoption of improved potato varieties by 47.8%. Farmers' membership to an institution/organization is essential for accessing and disseminating new information and new technologies. The possible reason for this might be membership of household heads in social organizations increases their awareness level of technologies as they are easily exposed to information and creates good network that leads them to easily access to credit and essential agricultural inputs such as improved seeds, chemicals, and fertilizer. This result is consistent with the findings of Aman and Tewodros (2016) and Mengistu *et al*. (2016).

Perception on yield capacity: Farmer's perception of improved potato variety was positively and significantly influenced adoption decision of improved potato varieties. Other variables held constant, farmer who perceive yield capacity of improved potato varieties is higher than that of local varieties have increases adoption decision of improved potato varieties by 51.3%. The possible reason for this might be if farmer's perception on yield of improved potato variety is superior to local variety, they more likely adopt and widely use those improved varieties. This result is consistent with the findings of Ermias (2013), Bayissa (2014).

4.3.2. Factors determining the intensity of adoption of improved potato varieties

This section focused on factors determining the intensity of adoption of improved potato varieties. Truncated regression which is the second stage of double hurdle model was employed in this section. The dependent variable was intensity of adoption of improved potato varieties in the study area, which represents the proportion of area allocated for improved potato varieties from the total area allocated for potato in percentage in 2017/2018 production season. Out of the total explanatory variables five variables found significantly influence the intensity of adoption of improved potato varieties. The significant variables were age of the household head, labor availability, and land holding size, livestock holding size and distance to the nearest market. The overall fitness of the model was found to be significant at 1% probability level. Detail of significant variables presented as follows.

Age of the household head: Age of the household head negatively and significantly influenced the intensity of adoption of improved potato variety at 5% probability level. Other factors kept constant, as the age of the household increase by a year the intensity of adoption of improved potato varieties decreases by 0.5%. The model result indicated that older farmers to be less likely to adopt improved potato varieties than younger farmers. The possible justification for this is that old household heads might reduce trust towards adoption of new technologies and this new technology need financial investments and intensive field managements. Hence, as age increases the proportion of land allocated to improved potato varieties declines. The result is consistent with Berihun *et al*. (2014), Bagheri (2015).

Labor availability: Labor availability in a household in adult equivalent was positively and significantly influenced the intensity of adoption of improved potato varieties at 10% significant level. Other factors kept constant, as additional one unit of labor in adult equivalent increases the intensity of adoption of improved potato varieties by 2.7%. The result indicates that the farmer with higher labor force are more likely to adopt and allocate more hectares of land for improved potato varieties. The possible reason for this may be that improved practices are labor intensive and hence the household with relatively high labor force uses the technologies on their farm plots more than the farmers with low labor forces. Similar studies for this findings are Mignouna *et al.* (2011), Chilot and Dawit (2016).

Land holding size: Land holding size positively and significantly affected the intensity of adoption of improved potato varieties at 5% probability level. Other variables held constant, a 1 ha increase in the total land holding resulted in 5.5% increase in the intensity of adoption of improved potato varieties. This implies that households who had more land holding may have more farm asset and would more likely to adopt the improved varieties and allocate more land for improved potato varieties than farmers who had less land holding. This result is consistent with Almaz (2008), Bagheri (2015), and Myrick (2016).

Livestock holding size (TLU): Livestock ownership in TLU positively and significantly influenced the intensity of adoption of improved potato varieties at 10% significant level. Other factors kept constant, a unit increase in livestock ownership in TLU increases the intensity of adoption of improved potato varieties by 2.9%. This may be farmers who had relatively large livestock might have more asset and which is source of income that can be used to purchase improved seed and other agricultural inputs and used in the production process (traction and transportation), may be able to allocate more land for improved potato varieties as compared to farmers who own relatively less livestock. In addition to this they can have more livestock products (farm yard manure) which is important organic fertilizer for potato production. In general the result indicated farmers with more livestock ownership allocating more hectares of land for improved potato variety production. The study is in line with Hassen *et al.* (2012), Victor (2016).

Distance to the nearest market: Distant to the nearest market negatively and significantly influenced the intensity of adoption of improved potato variety at 1% significance level. Other variables kept constant, an increases in distance from home to the nearest market by one kilometer decreases intensity of adoption of improved potato varieties by 1.7%.This implies that farmers who are far from market centers faces more transportation and transaction costs and hence could purchase less amount of farm inputs and sell outputs. This in turn results in reduced proportion of land allocated for improved potato varieties by farmers. This result is consistent with the findings of Bayissa (2014).

Table 8. Double- hurdle estimates of factors affecting adoption and intensity of IPVs

Factors	Probit regression			Truncated regression	
	Coefficients	Robust STD.Err	Marginal effects	Coefficients	Robust STD. Err.
Sex of the household head	-0.3573	0.4289	-0.1367	-0.0044	0.639
Age of the household	-0.0018	0.0150	-0.0007	-0.0048**	0.0023
Education status	0.4573**	0.1841	0.1808	-0.0243	0.0213
Labor availability	-0.0097	0.0888	-0.0038	0.0273*	0.0153
Land holding size	0.4003***	0.1537	0.1583	0.0551**	0.0224
Farm cash income	0.00002	0.00003	9.66e-06	5.26e-08	3.23e-06
Participation in off/non-farm activities	0.5014*	0.3004	0.1968	0.0522	0.0361
Livestock holding	0.1837*	0.1049	0.0726	0.0256*	0.0157
Access to credit	0.3283	0.2840	0.1295	0.0051	0.0422
Frequency of extension contact	0.6221***	0.1600	0.2459	0.0089	0.0194
Distance to the nearest market	-0.0513	0.0380	-0.0203	-0.0174***	0.0043
Membership to institution/ organization	1.3146***	0.2970	0.4776	-0.0293	0.0383
Perception on yield capacity	1.3940***	0. 3182	0.5130	-0.0244	0.0457
CONS	-5.4079***	1.0754		0.5784***	0.1635
Wald chi2(13)	58.01			107.1	
Prob> chi^2	0.0000			0.0000	
Log likelihood	-47.20			36.73	
Pseudo R^2	0.5732				
Number of observations	160			85	

Note: “***”, “**” and “*” represents the level of significance at 1%, 5% and10% respectively

Source: Own survey, 2018

5. SUMMARY, CONCLUSIONS AND RECCOMENDATIONS

This section summarizes the whole findings of this study and makes conclusions based on the results of the descriptive and econometric model. It also highlights some important policy recommendations for enhancing adoption and intensity of adoption of improved potato varieties by smallholder farmers.

5.1. Summary and Conclusions

Potato is one of tuber crops which plays a paramount role in ensuring access to food at the household level and can also generate income for smallholders, there by contributing to the economic sustainability of agricultural systems in some part of Ethiopia like that of Chilga *woreda*. Potato is the main crop cultivated and consumed in the study area. Regarding its contribution, the research-extension program of the national agricultural research system has been disseminating several high yielding improved potato varieties. However, the adoption and intensity of use of such improved varieties extended by the research system has not been researched so as to identify the gaps and make an intervention.

Therefore, this study was designed to address the prevailing information gap on the subject and contribute to proper understanding of the challenges and assist in improving adoption and intensity of adoption of improved potato varieties in the study area. The general objective of this study was to evaluate status of adoption and intensity of adoption of improved potato seed varieties in Chilga *woreda*. The study used cross sectional data to analyze demographic, socio economic, institutional and psychological factors on the adoption and intensity of adoption of improved potato varieties. To achieve the research objective primary data were collected from 160 randomly selected sample households through structured questionnaire. Secondary data were also collected from different sources, such as government institutions, Chilga *woreda* Office of Agriculture and Rural Development (CWOARD), each *kebele* office, different published and unpublished reports.

The study used both descriptive statistics and econometric model for analysis. The survey result showed that 53% of sample household heads were adopters of improved potato varieties in

2017/18 production year. The average proportion of area allocated for improved potato varieties (intensity) by adopter households was 63.8%. As a result, almost all adopter farmers planted improved potato varieties in combination with local potato varieties.

The double hurdle model was used to identify factors that determine adoption decision and intensity of improved potato varieties. The selection of the model was based on the assumption of independence between adoption decision and intensity of adoption of improved potato varieties and normal distribution of error terms. The result of double hurdle model showed that educational status of the household head, land holding size, participation in off/non-farm activities, livestock holding size, frequency of extension contact, membership to institutions/ organizations and perception on yield capacity were found significant and positive in the first hurdle (probit model) whereas labor availability, land holding size, livestock holding size were positively affected and age of the household head and distance to the nearest market negatively affected the intensity of adoption of improved potato varieties.

The findings of the study showed that some of the variables affected the adoption decision of improved potato varieties not affect the intensity of adoption and vice versa, which shows the model assumption of independent set of variables can affect the probability of adoption and intensity of adoption of improved potato varieties.

In the study area, the performance of farmers in terms of use improved potato varieties has not been to the expected levels.

5.2. Recommendations

On the basis of the empirical finding of the study, the following recommendations are suggested to be considered in the future intervention strategies which are aimed at promotion of improved potato varieties.

Age of the household head significantly and negatively affected intensity of adoption of improved potato varieties in the study area. Suggesting that extension organizations, research and other stakeholders' need of short-term training programs so as to share knowledge for older farmers and create awareness to them.

Education status of household head significantly and positively affected adoption of improved potato varieties. Therefore, diffusion of technology can be facilitated through educated farmers to be used as contact farmers. Therefore, any interventions that upgrade the knowledge of the households through education will better enhances farmers' adoption of improved potato varieties in the study area.

In the study area labor availability positively and significantly influenced intensity of improved potato varieties adoption. Therefore, policies and strategies need to consider availability of labor force or labor saving technologies before introducing labor intensive technologies.

Land holding size had positive and significant effect on adoption and intensity of adoption of improved potato varieties in the study area. Since land size is fixed in nature, it is not possible to increase land holding size. Hence, strengthening productivity increasing technologies is needed.

Participation in off/non-farm activities significantly and positively affected the adoption decision of improved potato varieties. Therefore, we need to encourage farmers' participation in off/non-farm activities to enhance the adoption of improved potato varieties.

Livestock holding size positively affected adoption and intensity of adoption of improved potato varieties. This suggested that encouraging and helping farmers in improving livestock productivity through providing improved veterinary services, better livestock feed (forage) and adopting high yielding breeds can lead to an improvement in adoption and intensity of adoption of improved potato varieties.

Frequency of extension contact positively affected adoption of improved potato varieties. This suggests strengthening the extension services to improve farmers' awareness about the benefits of using improved potato varieties.

Distance to the nearest market significantly and negatively affected intensity of adoption of improved potato varieties in the study area. Therefore development of market infrastructure and strengthening supportive institutions is need to improve adoption of improved potato varieties.

Membership to institutions/organizations positively and significantly affected adoption of improved potato varieties. Therefore, farmers' institutions/ organizations need to be strengthened so as to enhance the adoption of improved potato varieties in the study area.

Perception on yield capacity significantly and positively affected adoption of improved potato varieties. This suggest a need of short term training and experience sharing program to show the farmers practical experience to facilitate adoption.

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7. APPENDICES

Appendix I: Tables

Appendix Table 1: Multicollinearity test results for the explanatory variables

Variables	VIF	1/VIF
Sex of the household head	1.22	0.819
Age of the household	1.14	0.875
Educational status	1.29	0.774
Labor availability	1.39	0.717
Land holding	1.16	0.862
Farm cash income	1.10	0.908
Participation in off/non-farm income	1.37	0.731
Livestock holding	1.41	0.708
Access to credit	1.10	0.911
Frequency of extension contact	1.40	0.715
Distance to the nearest market	1.18	0.845
Membership in institution/organization	1.10	0.909
Perception on yield capacity	1.18	0.845
Mean VIF	1.23	

Source: data result, 2018

Appendix Table 2: Conversion factors for adult equivalent

Age group (years)	Male	Female
Less than 10	0.60	0.6
10-13	0.90	0.80
14-16	1.00	0.75
17-50	1.00	0.75
Greater than 50	1.00	0.75

Source: Stork *et al.,* 1991.

Appendix Table 3.Conversion factors for Tropical Livestock Unit (TLU)

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	Calves	0.25

Source: storck *et al*, 1991

Appendix Table 4.Test statistics for comparison of double-hurdle with Tobit Model

	Tobit	Double hurdle	
		Probit	Truncated
Wald/LR χ^2	133.91	58.01	107.1
Prob > χ^2	0.000	0.000	0.000
LOG-L	-102.11	-47.20	36.73
Number of observations (N)	160	160	85
Log likelihood ratio statistics	Γ =183.28> χ^2 (13)=27.688		

Source: Data result, 2018

Appendix II. Survey questionnaire

Study title: Adoption of Improved Potato Varieties by Smallholder Farmers: The Case of Chilga *Woreda*, North Gonder Zone, Ethiopia

I. Identification data / general information

1. Household head code number …….
2. Date of interview…….
3. Name of enumerator and mobile phone …….. And ……..
4. Name of the respondent's kebele administration ……. …. village (*Got*) name…….
5. Checked by supervisor ……Signature …….Date …….
6. Adoption status of household head: 1= adopter 0= non adopter

II. Household demographic characteristics questions

1. Sex of the household head? 1. Male 0. Female

2. Age of the household head .....years old.
3. Educational status of the households head? 0. Illiterate 1. Read and write
   2. Primary (1-8) 3. Secondary and above
4. Marital status 1. Single 2.Married 3.Divorced 4.Widowed
5. How many is the number of member of the household? ……....Males and ……..Females
   5.1.Number of active household members aged between 15-64 years
   Male ……Female ……total……
   5.2.Number of non-productive household members aged between<15 &>65 years.
   Male ……Female ……total……
6. Household labor availability (Please fill the table for all household members who were in the last 12 month living in your home).

	Age group	Numbers (#)		Activities participated in	Nature of participation (Tick√)	
		Male	Female		Full time	Part time
1	<10					
2	10-13					
3	14-16					
4	17-50					
5	51-65					
6	Above 65					
	Total					

Potato production activities include; 1) Land preparation 2) Sowing 3) Weeding 4) Cultivation 5) Harvest 6) Transportation 7) Storage 8) Marketing 9) All 10) others (specify)

7. Did you have potato farming experience during last production year? 1. Yes 0. No
   7.1.If "YES", how many years of potato farming and improved potato farming experiences do you have? ……..and …….years respectively.

III. Socio economic questions

1. Do you have own land? 1. Yes 0. No
   1.1. If "YES", how much is the total landholding owned by household heads (ha)?

Total land holding	Cultivated own land	Grazing	Rented in (2009)	Rented out (2009)	Shared in (2009)	Shared out (2009)

2. What are your main sources of income in 2009 E.C (in order of importance)?

1. Crop sale 3. Both crop and livestock sale
2. Livestock sale 4. Off-farm&/non-farm income 5. Others specify ----------

3. Annual income from agricultural production

3.1.Annual farm income in 2009 E.C?

From Crops	Quan. Produced/qt	Consumed/qt	Sold /qt	Unit price/ qt	Total rev. (ETB)	From Livestock and its product	No. sold	Unit price	Total revenu
Teff						Cow			
Wheat						Ox			
Barley						Beef			
Sorghum						Calf			
Maize						Heifer			
Potato						Bull			
Ginger						Sheep			
Sesame						Goat			
Cotton						Chickens			
Legumes crops						Donkey			
Spices						Horse			
Others						Mule			
						Egg			
						Milk/butter/cheese/yoghurt			
Total						*Total*			

Purpose of sale from livestock and its products only*; 1) For purchasing farm inputs 2) For settling debts 3) For buying clothes for family 4) For buying food for family consumption 5) Others (specify)* _____

3.2.Estimate the amount of income you got from byproducts of crops and livestock ……birr.

3.3.Total estimated farm income …… birr.

3.4..How much expenditure did you incur for family consumption in 2008 E.C?

	Clothing	School. Fee	Tax	Social obligation	Health Care	Food	Others	Total
Expenditure (ETB)								

4. Do you participate off /non-farm income activities? 1. Yes 0. No

3.1. If "yes", mention some of the major activities and how much birr you earn in the last one year.

S.No.	Type of income	Yes/No	Total income (ETB)
1	Petty trading		
2	Remittance from relatives		
3	Salary for non- farm jobs		
4	Gifts		
5	From aid		
6	From pension		
7	Sales of farm assets (machineries, building ,trees, agricultural tools)		
8	Sale of non -farm assets (TV,Fridge,etc)		
9	Other		
	Total		

3.2.Total estimated non -farm and off-farm income …….. birr.

5. How many of the following types of livestock do you have? Please fill in the head count row.

Cattle					Small ruminant		Equine		Poultry
Cow	Oxen	Bull	Heifer	Calf	Sheep	Goats	Donkey	Horse	

IV. Institutional related questions

1. Do you have access to credit from any sources? 1=Yes 0= No

If "yes", how much money \did you borrowed during the past one year? Total of …….. birr.

Credit source	Purpose	Have you ever asked For collateral? 1) Yes 0) No	Have you take credit in last 5 Years? 1)Yes 0) No If no, why?
1) Cooperative *2) Microfinance* *3) NGOs* *4) Local money lender* *5) Credit and Saving inst.* *6) Commercial bank* *7) Other*	*1)Improved potato seed purchasing* *2)Fertilizer and Chemical purchasing* *3)Purchasing food for household consumption* *4) Land rent* *5) Animal for traction* *7) Irrigation investment* *6) for non-farm business* *7) Other*	*If Yes, What types of Collateral requested?* *1) Land* *2) Livestock* *3) House* *5) Membership to farmers organ* *6)Other specify____*	*1) Highest interest rate* *2) No need* *3) Lack of collateral* *4) Less capacity to repay the loan* *5) No credit service available* *6) others*

2. **Did you get agricultural extension service on potato production?**

1. Yes 0. No

2.1. If yes, how often (frequency) the extension agent contacted you in 2009/10 production year? _____.

2.2 .What type of services did you receive from extension agents?

a. Training about improved seed c. Irrigation use

b. Advice about new technologies d. Fertilizer use

e. Others specify _____

2.3. Who is the source of extension service?

1. Research centers 3. NGO
2. Districts office of agriculture 4. Others

2.4. When does extension agent visit you?

1. Land preparation 3. During sowing
2. During input provision 4. Whenever disease/ pest occur
5. During variety selection 6. Others_____

2.5. Do you visit extension agent? 1. Yes 0. No

If yes, when do you visit?

1. during sowing for technical advice

2. during input provision to obtain and use improved seed variety
3. It depends (any time when there is technical problem)
4. Others (specify) _____

2.6. What was the means of information exchange?

1. Demonstration 4. Written materials (leaflets or manuals)
2. Field day/visit 5. Others (specify) _____
3. Training

2.7. Are the extensions advisors always available when you need help? 1. Yes 0. No

2.8. What are the problems you encountered when you are contacting extension advisors? _____

2. How far is your home from the nearest market that you buy farm inputs (improved potato seed) and sell outputs? In distance _____kms or in time _____-hours of walking (one way).
3. How far your home from input supply institutions? In distance ……kms (one way) or in time ……..hours (one way).
4. Are you a member of any social organization? 0. No 1. Yes

4.1.If yes what service do you get from the organization?

1. Loans/credit 2. Farm inputs (fertilizer, chemicals, and improved seeds)
3. Labor 4. Others (specify) _____

4.2. 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) _____

V. Potato production

1. Which local potato varieties did you grown in last production season? 1) Nech Ababa 2) Key Ababa 3) Shewie 4) America 5) Others, (specify) __
2. Did you use organic fertilizer for potato production? 1. Yes 0. No
3. If yes, which type did you use? 1) Farm yard manure 2) Compost 3) Crop residue 4) Other
4. Trends of potato cultivated by producer farmers?

Trends of potato production in last 5 years	Do you have access to irrigation for potato prod.? 1) Yes 0) No	Frequency of prod./year In 2009 E.C by		Potato storage method
1) Increasing 2) Decreasing 3) Constant	If yes, irrigated land in 2009_____	Rain fed	Irrigation	1) Postponed harvesting 2) Diffused light storage 3)Traditional mechanism

5. What are the opportunity of potato production, marketing and purchasing seed? _____

6. What are the problem/constraints of potato production, marketing and purchasing of potato Seed? (Multiple responses are possible).

Potato production constraints	Potato marketing problems	Constraint in purchasing seed
0) No problem *1) Shortage of land 2) Poor fertility of land 3) shortage of labor* *4) unavailability of seed* *5)Poor extension service* *6) poor input supply of fertilizers and chemicals* *7) natural factor problem* *8) lack of modern storage* *9) its perishability nature* *10) theft* *11) lack of cash* *12)lack of irrigation* *13)other*	*0) No problem* *1) Lack of sustainable demand for ware potato* *2) Low prices for ware potato* *3) Transportation problem* *4) Lack of market information* *5) Monopolization by organized groups* *6) Price fluctuation* *7) Tubers lost their quality in storage (desiccation, rotting)* *8)Other specify,_____*	*0) No problem* *1) Lack of information about recommended variety* *2) Non-availability of seed of required variety* *3) High seed price* *4) Need to travel long distances* *5) Credit facility not available* *6) Low seed quality* *7) lack of sustainable supply of seed* *8)Others specify,___*

VI. Adoption and improved potato seeds availability

1. How long since improved potato seed introduced in your village? _____years
2. Have you ever used improved potato seed varieties? 1. Yes 0. No
3. If yes, when did you start using? _____ Year.
4. When you decide to use new improved varieties of potato, which attributes is important for you?
    1. Easy to implement and apply
    2. Observability
    3. Provide high economical gain

4. Compatibility (Technical, cultural and farming system)
5. Availability
6. Other_____

5. Have you been using IPV continuously since you started? 1. Yes 0. No
6. Did you use IPV in the last two years production season? 1. Yes 0. No
7. Did you use improved potato varieties in 2009E.C cropping season? 1. Yes 0. No
8. If no, what is your major problem that hindered you from using and further diffusion of Improved potato varieties adoption in the last production year?

1. High cost
2. Not available
3. Poor quality
4. labor demanding
5. Not applicable
6. Not profitable
7. Others_____

9. Which Improved Potato Variety you have grown so far and when you have grown them?

Variety	Year first Grow	Duration of use	Source of seeds	2009 grown	Land allocated(2009)	Seeds problem
Belete						
Jalenie						
Gudenie						
Others						

Codes; Source of seed: *1) Own seed saved 2) Purchase from market 3) Union/Cooperative 5) Neighbors farmer 6) NGO 7) DOA 8) Specialized seed growers 9.Others*
Problem of released varieties: *0. No problem 1. Low yielding 2. Susceptible to LB 3. Susceptible to bacterial wilt 4. Late maturing 5. Small tubers 6. Low marketability 7) Not tasty. 8. Germination problem 9. Other*
Reason of stop using*: 1.unavailability of better variety 2) Unavailability of seeds 3) High seed purchase price 4) Low yield in my field 5) Disease and pest problem 6) Others (Specify)* _____

10. Do you have access to quality improved potato seeds? 1. Yes 0. No
11. Did you perceive improved potato seeds available on time? 1. Yes 0. No
12. How much does the timeliness availability of IPV affect your level of adoption?

1. No effect
2. Less affect
3. Somewhat affect
4. High effect
5. Very high effect

13. Do you think that the improved potato 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. Disease resistance 0) No 1) Yes 4. Perishability Resistance 0) No 1) Yes

15. What is your perception towards the adoption of improved potato in your locality?

_____

VII. Intensity of adoption of improved potato varieties

1. Total area allocated for potato production in 2009 E.C? _____(ha)
2. Total area coverage by improved potato varieties in the 2009 E.C?

Varieties	Area coverage in (ha) (2009 E.C)	Amount of seed used (qt)/ha In (2009 E.C)	Productivity/yield/ha in qt (2009 E.C)
Improved			
Local			
Total			

3. Did you apply the following agricultural input and its extension package as recommended by extension (DA) for potato production in 2009 E.C year?

Package	1)Yes 0) No Input	If no, why?	Quantity used/ha		Impact of your Modification?	Source of fert./pest
			What did you do?	Quantity /ha		
Improved seed/qt						
Row planting						
Urea/kg						
DAP/kg						
Herbicide/kg/lt						
Fungicides/kg/lt						
Insecticide/kg/lt						

***Code; Reason**: 1) High cost 2) Not available 3) Poor quality 4) labor demanding 5) Not applicable 6) Not profitable 7) others*

***What did you do for improved varieties:** 1) Higher seed rate 2) Lower seed rate 3) Mix of varieties **4)** other*

***What did you do for row planting:** 1) Wider row 2) Narrow row*

***What did you do for Fertilizer:** 1) Increasing 2) Decreasing 3) Broad casting for row planted potato 4) Using DAP or UREA alone 5) Additional use of organic fertilizer*

***What did you do for Herbicide/Fungicide/Insecticide:** 1) Higher rate 2) Lower rate 3) Increasing frequency 4) Decreasing Frequency*

***Impact of modification**: 1) Increasing productivity 2) Reduce labor 3) Reduce cost 4) Simplicity 5) other*

***Source**: 1) Own 2) Purchase from market 3) Union 4) NGO 5) Neighbors farmer 6) DOA*