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ADOPTION OF WHEAT-CHICKPEA DOUBLE CROPPING AND ITS IMPACT ON YIELD AND FARM INCOME IN BECHO WOREDA, SOUTH WEST SHOA ZONE, OROMIA REGION, ETHIOPIA.

DESALEGN HAILEYESUS LENTCHO

A THESIS SUBMITTED TO SCHOOL OF GRADUATE STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN RURAL LIVELIHOOD & DEVELOPMENT

JUNE 14, 2019

ADDIS ABABA, ETHIOPIA

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DECLARATION

I, Desalegn Haileyesus, declare that, this thesis is my own original work and has not been presented in any other University. All sources of materials used for this thesis have been duly acknowledged. This thesis is submitted in partial fulfillment of the requirements for a Masters of Arts in Development Studies (Rural Livelihood and Development).

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Addis Ababa University, College of Development Studies, Center for Rural Development

This thesis work has been submitted for examination with my approval as a university advisor

Advisor's name: Signature

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Date _____________________

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DEDICATION

Dedicated to my dear son, Basliel Desalegn, so that, he may pursue his Ph.D. for betterment of humanity, inspired by this second M.A degree of his father.

ACRONYMS

AAU	Addis Ababa University
AGP	Agricultural Growth Program
ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
BBM	Broad Bed Maker
CASCAPE	Capacity Building for Scaling up of Evidence Based Best Practices in Agricultural production in Ethiopia
CSA	Central Statistics Agency
DA	Development Agent
DAP	Di-Ammonium Phosphate
DC	Double cropping
FAO	Food and Agricultural Organization
GHG	Green House Gas
HH	House Hold
MoA	Ministry of Agriculture
NGO	Non-governmental Organization
PSM	Propensity Score Matching
SB	Selection Bias
SMS	Subject Matter Specialist
TLU	Tropical Livestock Unit
USDA	United States Department of Agriculture

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ABSTRACT

Adoption of wheat chickpea double cropping is one of the measures presumed to enhance productivity and farm income given potential compatibility of the crops. Double cropping maximizes benefit from same area and season in suiting twice harvest in a single season. In light of this premise, this study was initiated to analyze adoption status of wheat-chickpea double cropping, factors affecting the adoption and its impacts on yield and farm income of farming households s in Becho Woreda, South West Shoa Zone, Oromia region, Ethiopia. The study used cross-sectional data collected from 203 smallholder farm households selected through two-stage stratified random sampling techniques. Descriptive statistics and econometric models were used to analyze the data. Probit model and propensity score matching method (psmatch2) were employed to analyze determinant factors of the adoption and the impact of adoption on yield and farm income, respectively. The binary probit model result indicated that sex of household head, farmer type (model or non-model), total tropical livestock unit (TLU), training on double cropping, access to improved seeds, access to broad bed maker(BBM) and access to fertilizer were significant factors affecting the likelihood of adoption of wheat-chickpea double cropping positively and significantly. But, involvement in non-farm income had negative and significant influence on the likelihood of adoption of wheat-chickpea double cropping. The result of the psmatch2 estimation showed that adoption of wheat-chickpea double cropping has significant impact on yield and farm income of the treated households compared to the control groups. The result showed that, treated groups harvested average wheat yield of 21.2 Q/ha ,while the control groups harvested average wheat yield of 14.2 Q/ha with a difference of 6.9Q/ha. In line with farm income, keeping other farm income constant for both the treated and controls; the treated households earned average annual farm income of about 22,692 birr per year from sale of both wheat and chickpea as adopters while the control smallholders earned average farm income of 4128 birr from sale of wheat as non-adopters (mono-croppers) at statistically significant level (t=3.46 for yield and 5.34 for farm income). The findings suggest that, Ministry of agriculture (MoA) and its relevant stakeholders need to focus on promoting double cropping practice as one feasible measure in Vertisol dominant areas so as to exhaust the opportunity from the cropping system. The promotion of the double cropping system need to be supported by the provision of proper training on double cropping, better access to improved seeds, better access to efficient broad bed maker (AYBAR brand or better),efficient support in livestock productivity, and better timely access to recommended fertilizer.

Key words: **Adoption, Determinant Factors, Double Cropping, Farm Income, Yield**

CHAPTER ONE

INTRODUCTION

1.1. Background

In Ethiopia, agriculture is a dominant economic sector which makes a lion share contribution to the Gross Domestic Product, employment and foreign exchange earnings. Agriculture is still believed to remain a sector that plays an important role in stimulating the overall economic development of the country in the years to come (CSA, 2016). Double cropping maximizes benefit from same area and season in suiting twice harvest in a single season, planting wheat for instance in main season and chickpea on residual moisture immediately after harvest of the main season crop. To that effect, it is a key to look for best combination and compatibility of both crops to exhaust the opportunity from the double cropping system (Beuerlein, 2001). Association of bread wheat and chickpea has the highest biological efficiency, largest total productivity and the optimal monetary return. Thus, the combination will be useful to address both the food requirement and cash needs of farmers (Tsedalu, et al, 2018).

Double cropping has many advantages, such as reducing the risk of field loss due to drought, insect and disease; obtain a better use of vertical space and time in limited farmland. It is also important to note that, in the era of continuous land fragmentation, cropping system such as double cropping that intensify yield vertically are of great options to be included in the package for promotion (Beuerlein, 2001; Sandler,2014; Tsedalu,et al 2018;). Double cropping practice improves soil structure and soil fertility. It allows better distribution of water and nutrients through the soil profile, which in turn contributes to increase in yields and better productivity. Besides yield advantage, the benefit of planting chickpea as subsequent crop after wheat in double cropping is equivalent to application of 60 kg N/ha as fertilizer, through attractive feature of chickpea in its ability to fix atmospheric nitrogen in symbiosis with rhizobia. As this is very healthy, it contributes to sustainable agricultural system (Endalkachew et al., 2018).

To develop feasible and sustainable double-cropping system, production factors such as length of growing season, cropping sequence, compatibility of crops with the season, biological complementarity, and planting time must be considered. Under such considerations, chickpea and grass pea grow as a double-crop after cereals such as barley, wheat and teff sequentially, in the same season (Muluneh et al., 2014).As one of a big element in double cropping of wheat and chickpea, Vertisol management need to paid due attention. Properly draining excess water from the soil is important during the main rainy season. Once excess water is drained from the Vertisol by using broad bed maker (BBM) or related practice, early planting of the main season crop such as wheat or barley will be possible. Through efficient Vertisol moisture management mechanisms, one can produce subsequent crops such as; chick pea, lentil and vetch after the main season crop (MoA, 2014). In double cropping practice, the preceding crop should be physiologically dissimilar crop (example: cereal such as wheat; to legume such as chickpea and likes) is recommended, in order to minimize the problem of nutrient imbalance and pest build up (Marcellos, et al., 1991; Endalkachew, et al., 2018).

Ethiopia has potential for double cropping practice in its Vertisol dominant areas such as; West Shoa zone, South West Shoa zone, North Shoa Zone of Oromia region and West Gojjam, East Gojjam, North Gondar and South Gondar Zones of Amhara region (MoA, 2014).

Selection of early maturing varieties of both commodities and early planting of the first, in the main season is of paramount importance in double cropping practice. Early planting of compatible variety such as ‘Hidase’ wheat mainly (early June) makes more compatible to cultivate chickpea and grass pea. As the main crop (Hidase Variety for example) matures in September, leaving adequate growth period for the second crop, chickpea or grass pea, which helps to intensify the productivity of the land. The relative short maturity of Hidase wheat variety which is 100-110days as compared to maturity time for Sanate (141 days) Danda’a (145 days) made the crop compatible to the double cropping practice. Farmers in Becho woreda are widely using the variety (MoA, 2014, CASCAPE, 2015).

1.2. Statement of the problem

Ethiopia is facing challenging problems induced by land degradation, increasing soil fertility problem, rapid population growth, and socio-economic constraints. These problems and constraints are adversely affecting agricultural production and national food security. The country has been a net importer of food for decades in its struggle to feed its population. Better cropping practice such as double cropping need to be adopted and put to use where ever possible to sustainably increase productivity and contribute to food security (Tsedalu et al, 2018). Wheat is an important food security crop in Ethiopian diet. Although the country is the second largest producer of wheat in sub-Saharan Africa, it could not yet meet the national demand and large amount is being imported from abroad. The national mean wheat grain yield is still low. Transforming the crop productivity by double cropping it with an important crop such as chick pea, contributes to food security, nutrition security and improves the increasing soil fertility problem (Muluneh et al., 2014, CASCAPE, 2015). As chickpea is rich in protein, double cropping of wheat with chickpea contributes in alleviating malnutrition and improving human and soil health (Million & Asnake , 2017).

Over 50% of all smallholder farmers in Ethiopia operate on one (1) hectare or less. Smallholder producers, which are about 12 million households, account for about 95% of agricultural GDP. Agricultural production in the country is mainly subsistence (Infomineo, 2016). Small holders land in the country is getting fragmented time to time, as rural population is increasing over years. Population of the country has been increasing rapidly over the past four decades, from 35 million in the 1980s to 99.4 million in 2015 and passed 100 million in 2017. This has a huge implication on the growing food and nutrition security issue to systematically be worked on by applying efficient cropping systems (Minot et al 2015)

With regards to impacts of adoption of double cropping on yield, Crabtree et al. (1990) conducted a study comparing mono-crop and double-cropping of wheat with legume soybean and concluded that, grain yields for wheat were less in double-cropped systems compared to mono-crop systems by 5Q/ha. In addition to this, Zhang & Li (2006) also raise the study conducted in Missouri United States on the double-cropping system of wheat (*Triticum* *aestivum* L.) followed by soybean [*Glycine max* (L.) stated that, yields of double cropped commodities was 10-40% less than the full season crops.

Contrary to the above, Marcellos et al. (1994) conducted a study on impact of double cropping of wheat and chickpea on grain yield compared to the mono cropping and found out that, 40-50% grain yield increase from double cropping compared with wheat after wheat mono cropping. Besides, study conducted by Sanford et al. (1973) as cited Sandler (2014) found that wheat had a threefold greater yield advantage following soybean than grain yield in mono cropping, which was attributed to the soil nitrogen fixing properties of soybean.

As seen in the above two paragraphs, double cropping has opposing results with regards to yield. This might be attributed to different factors of socio economical, institutional and demographic factors. This shows that, adoption and its impact are context specific and based on this background; this study is partly interested to assess yield impact of double cropping compared to mono crop in the context of Becho woreda.

On top of this, Muluneh et al (2014) studied double-cropping of early-maturing improved forage crops and residual soil moisture-based planting of grass pea in central highlands of Ethiopia in a close by areas to Becho; on the basis that it improves feed availability and land productivity. Given his study is on animal feed availability (forage crops and grass pea), the current study is purposed to contribute to human food availability (wheat and chickpea).

With regards to factors affecting adoption of agricultural technology, Cruz, (1987; 45) stated "Farmers are major constraint in development process; as innovators or laggards." The author adds that, there are number of factors that influence the extent of adoption of technology such as characteristics of technology, the adopters, which is the object of change, the change agent (extension worker, professional), and the socio-economic, biological, and physical environment in which the technology takes place (Cruz, 1987). The study conducted by Paul, (2017; 48) stated "Age, gender, farmer experience, education, access to extension services, distance to nearest market, ownership of appropriate farm machines, available land and labor for cultivation and the presence of shocks like rainfall are determinant factors of agricultural technology adoption". In addition, major inhibitors affecting farmer's adoption of different agricultural technologies are Farmer type (being a model farmer have more chance to adopt than the non-model farmer), access to irrigation, total annual income, access to input supply and frequency of extension contact (CASCAPE-AAU, 2015).

Although the studies above seem the same from the point of determinant factors of agricultural technology adoption they came up with relatively diverse outputs. As the current study is on adoption of double cropping; it aimed to contribute to richness of research outputs in the area of agricultural technology adoption from the point of factors affecting its adoption in general and of wheat-chickpea double cropping in particular.

Asaduzzamam *et al.*, (1989) stated that, practice of wheat –chickpea double cropping is very poor in Ethiopia. Besides, Tsdalu, et al (2018) stated that North Gondar zone has a high potential for double cropping of wheat and chickpea per one growing season. Farmers in the area, however, do not practice double cropping so far, Apart from showing the high potential of the area and attributing low adoption of double cropping to lack of research outputs, the source did not show research outputs on factors affecting wheat chickpea double cropping; which initiated this study. Mid altitude of Becho woreda has a high potential to practice double cropping of wheat and chickpea in one cropping season. The high retention of Verisol in the area and the rain fall distribution is an opportunity. Despite the potential and wide ranges of benefits from double cropping of wheat and chickpea, only some of the farmers in the woreda are engaged on double cropping (MoA,2014; CASCAPE, 2015).

As per the above paragraph, in different parts of the country, double cropping is reported to be feasible but not well advancing as mono cropping. So, what are the factors hindering its move? This might have implication on the adoption decision of farmers. Farmers decide to adopt based on the utility (yield advantage/ farm income increment or the reverse) they get from the adoption of the technology. Hence, this study attempts to assess factors impeding farmers decision with regards to double cropping of wheat-chickpea in Becho woreda along with utility it may have for farmers or the reverse.

In general, against the backdrop of these gaps, this study, therefore, aimed to examine adoption status of wheat-chickpea double cropping, factors affecting the adoption and its impact on yield and farm income of the small holder farmers in Becho woreda, South West Shoa Zone, Oromia region, Ethiopia.

1.3. Objective of the study

The general objective of the study is to assess adoption status of wheat-chickpea double cropping along with its determinant factors and its impacts on grain yield and farm income on selected HHs in Becho woreda.

The specific objectives of the study are:

1. To assess the status of adoption of double cropping of wheat and chickpea in Becho woreda.
2. To analyze factors affecting adoption of double cropping of wheat and chickpea in the study area.
3. To assess impacts of adoption of wheat - chickpea double cropping on grain yield and farm income of the selected households in the study woreda.

1.4. Research questions

1. What types of farmers conduct double cropping of wheat and chickpea in Becho woreda?
2. What is adoption rate of wheat-chickpea double cropping in Becho woreda?
3. What are the main institutional, socio-economic and demographic factors affecting the adoption of wheat-chickpea double cropping?
4. Does adoption of wheat-chickpea double cropping significantly increase productivity and farm income?

1.5. Significance of the study

The study identified important factors which hinder success in the likelihood of adoption of wheat-chickpea double cropping and also estimated impact of adoption on yield and farm income of smallholder farmers in the study area. There was no enough empirical evidence on the adoption status, factors affecting adoption of wheat-chickpea double cropping and its impact on yield and farm income in Oromia region in particular and in Ethiopia in general. And hence, this study could contribute to the knowledge gap in the area. It is crucial to understand the status of adoption, factors that affect farmers' decision to adopt wheat chickpea double cropping along with its impact on yield and farm income.

Result of the study enables to see areas of intervention by concerned bodies for better scaling of the double cropping technology as it is useful to the small holder farmers; in such time when rural land is getting fragmented and is becoming an issue in the highly growing rural population. Without a need for additional land, small holder could cultivate wheat and chickpea on the same land in the same season by adopting double cropping. Impact assessment in terms of yield and farm income showed that, adoption of wheat-chickpea double cropping have greater positive economic evidence favoring adopters over the non-adopters. As this highly contributes to food security, it is believed to encourages the non-adopters to begin adopting the technology and benefit from the cropping system.

Generally, the result of the study can contribute to the growing body of literature and can also be used as a reference material for future researchers in the area. The findings of the study can also contribute to the related works being done by AAU-CASCAPE project in particular.

1.6. Delimitations /scope/ of the study

This study is delimited in different ways. Geographically, it is delimited to Becho woreda, South Western Shoa Zone, Oromia region, Ethiopia. Commodity wise, the study is delimited to specific double cropping practice of wheat and chickpea; with wheat to grow in main season and chickpea to grow with residual moisture after harvesting of wheat, on rain fed status. Besides, as 85% of the Becho is covered by Vertisol, the study is delimited to vertisol dominated areas of the woreda. Methodologically, the study is delimited to descriptive and inferential statistics. With regards to descriptive statistics, the study is delimited to using t-test, Pearson chi-square test (X^2), mean, standard deviation, minimum and maximum values. With regards to the inferential statistics, econometric models such as binary probit model for analyzing the determinant factors and propensity score matching (psmatch2) model for estimating impact of adopting the wheat-chickpea double cropping on yield/ha and farm income in birr per annum. Generally, the study is delimited to adoption and determinants of

Wheat - Chickpea double cropping and its impacts on yield and farm income in the target woreda. The farm income assessment is delimited to annual income from sale of the target crops only (wheat and chickpea for adopters and wheat for the non-adopters) keeping other farm incomes constant.

CHAPTER TWO

LITERATURE REVIEW

2.1. Conceptual and theoretical review of agricultural technology adoption.

Agricultural technology adoption refers to a decision to make full application of an innovation as the best course of action. Adoption also denotes the integration of an innovation into farmers' normal farming activities over an extended period of time (Feder *et al*. 1985). Adoption as a process can be defined as the mental process through which individual farmers pass from first hearing about an innovation or technology to final adoption. This indicates that, adoption is not a sudden event but a process. Farmers do not accept innovations immediately; they need time to think over things before reaching a decision (Rogers, 1983). Adoption can be classified as farm level or as an aggregate level adoption. Adoption at individual farmers' level is defined as the degree of use of new technology in long run equilibrium when an individual farmer has full information about the new technology and its potential. Regarding aggregate adoption behavior, diffusion process is defined as the spread of new technology within a region. This implies that aggregate adoption is measured by the aggregate level of specific new technology with a given geographical area or within the given population. Adoption is not a permanent behavior. An individual may decide to discontinue the use of an innovation for different reasons such personal, institutional social, and the availability of an idea or practices that is better in satisfying his or her needs (Feder *et al*., 1985; Galmesa, 2018). On the other hand, rate of adoption is defined as the percentage of farmers who have adopted a given technology (Nkonya et al, 1997).

On the basis of the four core elements, Rogers (1983) summarized concept of agricultural technology adoption as; technology that represents new idea, practice, or object being diffused; communication channels which represent the way information about the new technology flows from change agents suppliers (extension, technology suppliers) to final users or farmer; the time period over which a social system adopts a technology and the social system. Overall, the technology diffusion process essentially encompasses the adoption process of several individuals or farmers over time. Until it was modified by Rogers and Shoemaker, the dominant five-stage of classical adoption process model was formulated by the North Central Rural Sociology Committee (1961). In its well modified version, 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 is composed of the following five stages adoption process: awareness stage /first hear about the innovation/; interest stage /seek further information about an innovation); evaluation stage (weigh up the advantages and disadvantages of using it/; trial stage /test the innovation on a small scale/ and adoption stage /apply the technology on a large scale in preference to old methods (Rogers, 1983).

Agricultural Transformation in many developing countries that led to a significant increase in agricultural productivity resulted from programs of agricultural research, extension and infrastructural development occurred in the late 1960s, and this revolution was known as Green Revolution. Green Revolution refers to a rapid increase in wheat and rice productivity resulted from the adoption of improved seed varieties, fertilizers and pesticides. Technological change in agriculture comprises of introduction of high yielding variety of seeds, fertilizers, plant protection measures and irrigation. These changes in agricultural sector enhance the productivity per unit of land and bring about rapid increase in production (Aynalem et al. 2018; 99).

2.2. Concept of double cropping technology

Double cropping is a production system that includes the growth of two separate crops (cerials with legumes/pulses) at different times in the same growing season; involves the harvesting of one species followed immediately by the planting of another compared with mono- cropping (Sandler, 2014). Besides, Nafziger,(1985) stated, “Double cropping (also known as sequential cropping), is the practice of planting a second crop immediately following the harvest of a first crop, thus, harvesting two crops from the same field in one year.

Annual agricultural output could be nearly doubled through use of double cropping without farmland expansion. It is essential for places where land is getting fragmented as population is currently increasing in countries like Ethiopia. The adoption of improved chickpea varieties in addition to cereals like wheat varieties have the potential to contribute not only to food security but also to economic growth and development as well as poverty reduction among the poor, since the adoption of such improved varieties are both pro-poor and environmentally friendly in such time; when natural resources are getting degraded (Paul, 2017; Kawasaki, 2018). The rotation with the cereal immediately followed by a pulse crop as a double cropping practice is profitable without the need for fertilizer N; that increase grain protein (Cox, et al., 2010).

Bread wheat (Triticum aestivum L.) is an annual crop plant belonging to the family Poaceae (grass family) and native to the Mediterranean region and southwest Asia. Wheat was brought to Ethiopia together with barley from southwestern Asia after the time, domestication of cereals such as teff and millet began in northern Ethiopia at least 4,000 years ago. Although bread wheat is the most important crop in Ethiopia, its productivity is very low as compared to the productivity of world bread wheat which is attributed to poor agronomic practices (Abiot, 2017).

On the other hand, chickpea (Cicer arietinum L.) is a high value ancient annual grain legume (pulse crop) that is used extensively for human consumption, commercialization purposes and fertility restoration. It has been growing in Africa, the Middle East, and India for centuries and is adapted to many countries of the world today. In Ethiopia, chickpea is typically grown on Vertisols that cover 12.3% of Ethiopian land mass. It is mostly known to grow as double crop and such cropping system increases the productivity of scarce land and provides an additional source of income (Lijalem, et al., 2016). The major chickpea growing zones in Ethiopia include: East Shewa, West Shewa and North Gonder (Million and Asnake, 2017). Chickpea's production takes place with residual moisture planted at the end of August or beginning of September. What makes it more convenient is that, both chickpea and wheat share common agro ecology on the Vertisol (McKay et al., 2002; Tsedalu, et al., 2018).

2.3. The importance of wheat -chickpea double cropping

Double-cropping uses resources more efficiently and produces more total grain in a single season without demanding more land for the other crop. It can increase potential profitability of farmers. Better land resource management, such as double cropping benefits small land holders in its contribution to food security and sustainable farming system. In double cropping practice, annual agricultural output could be nearly doubled without farmland expansion (Sandler, 2014; Million and Asnake , 2017; Tsedalu, et al. 2018; Kawasaki, 2018).

Double cropping could potentially maximize advantages from same area and season. It is a key to look for best combination and compatibility of crops to exhaust the opportunity from the system; such as, wheat followed by legume like chickpea. Double cropping reduces the risk of field loss due to drought, insect and disease, provides a better vertical space and time in limited farmland (Beuerlein, 2001 as cited in Tsedalu,et al., 2018).

Chickpea as the subsequent crop in double cropping practice has the ability to grow on residual moisture which gives farmers the opportunity to engage in double cropping, where chickpea is sown at the end of the rainy season following the harvest of the main crop such as wheat, barley and teff. Chickpea is considered less labor-intensive crop and its production requires less external inputs as compared to cereals. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea fixes atmospheric nitrogen (about 140 kg/ha) from air through bacteria (rhizobium) present in its roots and meets most of its nitrogen requirement; it also leaves substantial amount of residual nitrogen for subsequent crops such as wheat and adds some amount of organic matter to maintain and improve soil health and fertility. This saves the fertilizer input cost not only for chickpea but also for the subsequent crops in double cropping process. Because of its deep tap root system, chickpea can withstand drought conditions by extracting water from deeper soil layers. It also increases livestock productivity as the residue is rich in digestible crude protein content compared to cereals (McKay et al., 2002; Million and Asnake, 2017).

Double cropping practice allows better distribution of water and nutrients through the soil profile, improves soil structure and soil fertility which in turn contributes to increase in yields and better productivity. In the case of wheat and chick pea double cropping, increases in grain yield of wheat grown after chick pea compared with wheat alone, have been in the range of 40-50%. Besides yield advantage, the benefit of chickpea is the fact that it highly reduces the cost of chemical N fertilizer purchase since it fixes atmospheric nitrogen. By doing so, it contributes directly to grain protein and also reduce the need for N fertilizer for subsequent crops such as wheat. Decreases chemical Nitrogen fertilizer use through the practice of double cropping and substantially lowers related greenhouse gas (GHG) emissions (FAO, 2014, Marcellos, et al., 1991 Endalkachew et al., 2018).

Summarized advantages of double cropping include: Low input requirements such as fertilizers; as inoculated legume fixes its own nitrogen from the air and this causes low production cost which makes the farmers profitable, improves soil fertility, soil health, and the sustainability of production systems and by doing so, helps in increasing yield of both the main season cereal crop and the subsequent legume crop. Growing chickpea demand due to increasing domestic consumption and export markets provides a source of cash for smallholder producers, and currently increasing market prices encourage more adoption and more production, It reduces malnutrition and improves human health especially for the poor who cannot afford livestock products. It is an excellent source of protein, fiber, complex carbohydrates, vitamins, and minerals and it improves more intensive and productive use of land, particularly in areas where land is scarce and the crop can be grown as a second crop using residual moisture (Solomon & Bekele., 2010; Lijalem et al., 2016).

2.4. Global practice of wheat –chickpea double cropping

In Missouri as well as much of the Midwest and Southern United States, the most popular double-cropping system was winter wheat (*Triticum aestivum* L.) followed by soybean [*Glycine max* (L.) (Kyei-Boahen & Zhang, 2006). According to the study by Van Opstal et al., (2011), In humid areas of South America, double-crop systems gave higher productivity almost two times greater than the sole crop. Resource use was calculated as the product of the proportion of annual resources captured by crops to produce grain yield. In evaluating productivity, Caviglia et al. (2004) found that double-cropping dramatically increased the productivity (yield) on an annual basis.

In Illinois United States of America, double cropping of two crops—corn and soybeans—have come to dominate the cultivated area of the land over the past 60 years, moving from 60% of cropped acres in 1950 to more than 90% in recent years. Considerable effort has gone into trying to explain the yield increases found when corn and soybean are grown in sequence instead of continuously. One factor is the effect of Soybean's nitrogen (N) supply to the next crop (Nafziger, 1985)

The viability of the double cropping program, initiated in 1997 in North Korea following the catastrophic years of 1995 and 1996, is now well established and a substantial increase in the food grain availability has been achieved. The program has reduced substantially the need for food aid. In addition, the program provides food during the lean period from June to September when food shortages are most acute. The double cropping program started in 1997 with 47 000 ha. Since then additional areas have been brought under double crops each year. The area under the double cropping program amounted to 191 540 ha in 2001. The yield of double cropped wheat rose from 46 930 tons in 1996/97 to 204 125 tons in 1998/99 (Christine, 200).

USA suited to dry land winter wheat–soybeans, the most common double crop (DC) system increased by up to 28% from 1988 to 2012. Besides yield advantage of double cropping, in adapting US agriculture to the climate of the 21st century, number of experiments are being made on the cropping system as a key. In the US, DC of winter wheat and soybeans in particular has potential to increase resiliency of agricultural production as temperatures increase. In such a system, key times for yield formation in both crops occur outside of July and August—the months most likely to experience extreme heat in the US. Recent economic analyses of this production system also indicate that it has the potential to create higher farmer profits, with an increase of profitability of 27% in a double-crop system in 2013 in Illinois as opposed to single-crop corn (Seifert and Lobell. 2015)

2.5. The practice of wheat –chickpea double cropping in Ethiopia

In Ethiopia, there is no enough evidence documented on the double cropping between wheat and chickpea. However, as a synonym double cropping of chickpea with wheat has been found to be quite remunerative and advantageous. Even though evidences and promotions are not well advancing, there has been some practices in central parts of Ethiopia where cropping of principal crops (cereals) with precursor _chickpea (Asaduzzamam *et al.*, 1989). Chickpea has the ability to grow on residual moisture which gives Ethiopian farmers the opportunity to engage in double cropping, where chickpea is sown at the end of the rainy season following the harvest of the main crop. This allows more intensive and productive use of land, particularly in areas where land is scarce. It is also an excellent source of protein, fiber, complex carbohydrates, vitamins, and minerals thus can help alleviating malnutrition and improving human health (Million & Asnake, 2017).

Besides, double-cropping of early-maturing improved forage crops; residual soil moisture-based planting of chickpea or grass pea for example, could improve feed availability, labor and land productivity; as per the study conducted in certain parts of the central highland of Ethiopia (Muluneh et al, 2014).

Mid altitude of North Gondar zone including Dembia, G/zuria and Takusa have a high potential to produce two crops in one cropping season as a double cropping. The rain fall distribution combined with the high retention of vertisol, enables the area to support two crops of high compatibility viz., wheat under full rain fall and chickpea suit for partial phenological residual moisture. The soil in the area has vertic nature with high water holding capacity. However, farmers are still practicing sole cropping because there is neither verified research outputs not awareness created and promotion that support for the practicing of double cropping in the area (Tsedalu, 2018).

Although Becho woreda is identified as potential woreda to practice double cropping of wheat and chickpea, little is practiced in the area. Double cropping chickpea after wheat is particularly suitable in Becho when the main crop planned to leave the land before mid of September. An early harvest reduces the risk of catastrophic damage to the crop from high wind or hail. (AAU-CASCAPE, 2015)

2.6. Suitable agro ecology and required conditions for adoption of wheat and chickpea cultivation

Wheat is a temperate climate crop but is widely adapted to varying climate conditions across the world , it needs cool, dry and clear climate for better growth and yield., the optimum temperature range for growth is between 7 °c and 21 °c, The rainfall requirement is 750 to 1600 mm/year. Hot and humid climate is harmful because it encourages the infestation of diseases like rust, root rot etc., in early growth stage, it requires cool temperature and dew formation which increases tillering, very low temperature, cloudy atmosphere and frost during grain filling stage is harmful (Agri-Info, 2015). Since altitude strongly influences the temperature in Ethiopia, most wheat is grown at an altitude of 1500-3000 meters above sea level. The most suitable agro- ecological zones, however, fall between 1900 and 2700 masl. In general, bread wheat is widely cultivated in the highland and midland of Ethiopia. The major wheat producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Harerghe, Sidamo, Tigray, Northern Gonder and Gojam zones. (Ofcansky & Berry, 1991; Alvarez and Stanley,1961, as cited in Minot, et al., 2015). Vertisol (black soil) is very suitable for cultivation of wheat under better water draining system. Besides, wheat crop is grown in different types of soils ranging from desert soil to heavy clay soil well drained fertile soils such as Leptosols, Regosols, Cambisols and also performs on slightly acidic Andosol under good management (CACSAPE-AAU, 2015; Agri-info,2015).

With regards to chickpea, it performs better in Ethiopia on the altitude that ranges from 1400-2300 m.a.s.l; on temperature that ranges from 70-80°F or 21-26.6 °C / as 0°c equals 32 °F and in areas that get rainfall that amount 700-1300 mm/year. Improved varieties perform well between 1500-2600 meter asl (MoA, 2014). Chickpeas generally grow on heavy black or red soils which is deep; not shallow with good residual soil moisture content. It requires a soil pH of 6.0 to 7.0. In Ethiopia, chickpea is well adapted to the areas having Vertisols. For places with flat heavy clay soils, it is advisable to use ridge and furrow (RF) plots as it facilitate the removal of excess water from the field. Broad bed and furrow (BBF) can also be used on gentle slopes to get well established crop. Owing to its deep tap root, chickpea is fairly drought tolerant as it is able to extract moisture from deep layers of soil profile, but its productivity is reduced by the recurrence of the terminal droughts. Planting time is an important factor in increasing chickpea's yield. Occurrences of frost and hailstones can severely damage the crop (Million and Asnake, 2017).

Double cropping of wheat –chickpea is more appropriate on Verisol through better agronomic practices. Good to note that, draining of excess water from Vertisol field by using broad bed maker (BBM) and related practices is very important during the main season crop planting time. Accumulating the excess water for future use in moisture stress areas is also wise to do. Besides, for effectiveness of double cropping, carefully selecting improved early maturing and disease resistant or tolerant varieties, application of proper seed rate per hectare, application of proper soil and water conservation practice need to be considered (MoA, 2014).

Early planting of Hidase wheat variety mainly (early June) makes more compatible to cultivate chickpea and grass pea. As the main crop (Hidase) matures in September, leaving adequate growth period for the second crop, chickpea or grass pea, which helps to intensify the productivity of the land. The relative short maturity of Hidase wheat variety which is 100-110days as compared to maturity time for Sanate (141 days) Danda'a (145 days) made the crop compatible to the double cropping practice in Becho (MoA, 2014, CASCAPE, 2015).

Mid altitude of South West Shoa of Becho woreda zone has a high potential to produce two crops in one cropping season as a double cropping. The rain fall distribution combined with the high retention of Vertisol, enables the area to support two crops of high compatibility viz., wheat under full rain fall and chickpea suit for partial phenological residual moisture. The soil in the area has vertic nature with high water holding capacity (Muluneh et al, 2014, CASCAPE, 2015;). Besides, as 85% of the Becho woreda is dominated by Vertisol and it suits double cropping of both wheat and chickpea production (CASACAPE-AAU, 2015).

2.7. Review of empirical studies on determinants and impacts of double cropping.

There are number of factors that influence the extent of adoption of technology such as characteristics or attributes of technology; the adopters or clientele, which is the object of change; the change agent(extension worker, professional); and the socio-economic, biological, and physical environment in which the technology take place (Cruz, 1987). According to Aynalem, et al (2018;.99), "Variables such as accessibility of credit, farm size, distance from market, oxen ownership, and education were found to be the most common significant factors influencing adoption of agricultural technology in Ethiopia." In addition, Minot et al., (2015; 42) also add that; "The main factors influencing the distribution of wheat production in Ethiopia are rainfall and altitude, as altitude strongly influences the temperature in Ethiopia." Farmers have been seen as major constraint in development process (Cruz 1987). They are innovators or laggards. Socio-psychological trait of farmers is important. The age, education attainment, income, family size, tenure status, credit use, value system, and beliefs were positively related to adoption. The personal characteristics of extension worker such as credibility, relationship with farmers, intelligence, emphatic ability, sincerity, resourcefulness, ability to communicate with farmers, persuasiveness and development orientation. The conditions of the farm include its location, availability of resources and other facilities such as roads, markets, transportation, pests, rainfall distribution, soil type, water, services and electricity.

Farmer type (*being model than non-model*),access to irrigation, higher annual income earning, were found to positively influence adoption of wheat production technologies at 1% significance level. But, access to input supply and frequency of extension contact were found to positively influence adoption of wheat production technologies at 10% significance level (CASCAPE-AAU, 2015)

With regards to impacts of adoption of double cropping, Marcellos et al. (1994) conducted a study on impact of double cropping of wheat and chickpea on grain yield compared to the mono cropping and found out that, 40-50% grain yield increase achieved from double cropping compared with wheat after wheat mono cropping. Besides, study conducted by Sanford et al. (1973) as cited Sandler (2014) found that wheat had a threefold greater yield advantage following soybean than grain yield in mono cropping, which was attributed to the soil nitrogen fixing properties of soybean.

Endalkachew et al (2018) also reported that, in the case of wheat (Triticum aestivum) and chick pea (Cicer arietinum L.), double cropping increases grain yield of wheat grown after chick pea compared with wheat alone, in the range of 40-50%. In an experiment done by Tsedalu et al., (2018; 67) “Sole cropping of chickpea crop took longer maturity days (~ 110 days) than the wheat-chickpea combination, which took nearly 90 days.” Research comparing mono-crop and double-crop wheat systems using soybean showed that, double-crop systems increased grain yield and net returns of the overall system (Crabtree et al., 1990; Kyei-Boahen and Zhang, 2006; Caviglia et al., 2011).

2.8. Conceptual framework of the study

This study sought to establish the factors that affect adoption of wheat-chickpea double cropping in Becho woreda, South West Shoa Zone,Oromia region,Ethiopia. The study was guided by the conceptual framework in Figure 1 below. Farmers’ adoption behavior, especially in low-income countries is influenced by a complex set of socio-economic, demographic, technical, institutional and bio-physical factors (Feder et al., 1985). Practical experiences and observations of the reality have shown that, one factor may enhance adoption of technology in one specific area for certain period of time while it may create hindrance for other locations Tesfaye et al. (2014). Because of these reasons, it is difficult to develop a one and unified adoption model in technology adoption process for all specific locations.

Adoption of wheat-chickpea double cropping is the outcome of several factors. In such a way, adoption of wheat –chickpea double cropping is expected to be influenced by different key factors such as: Demographic factors socioeconomic factors, and Institutional factors which were independent variables and it was hypothesized that these variables have influence on the adoption of wheat-chickpea double cropping in the study area. The directions of the arrows show the interrelationships between the key variables of the study.

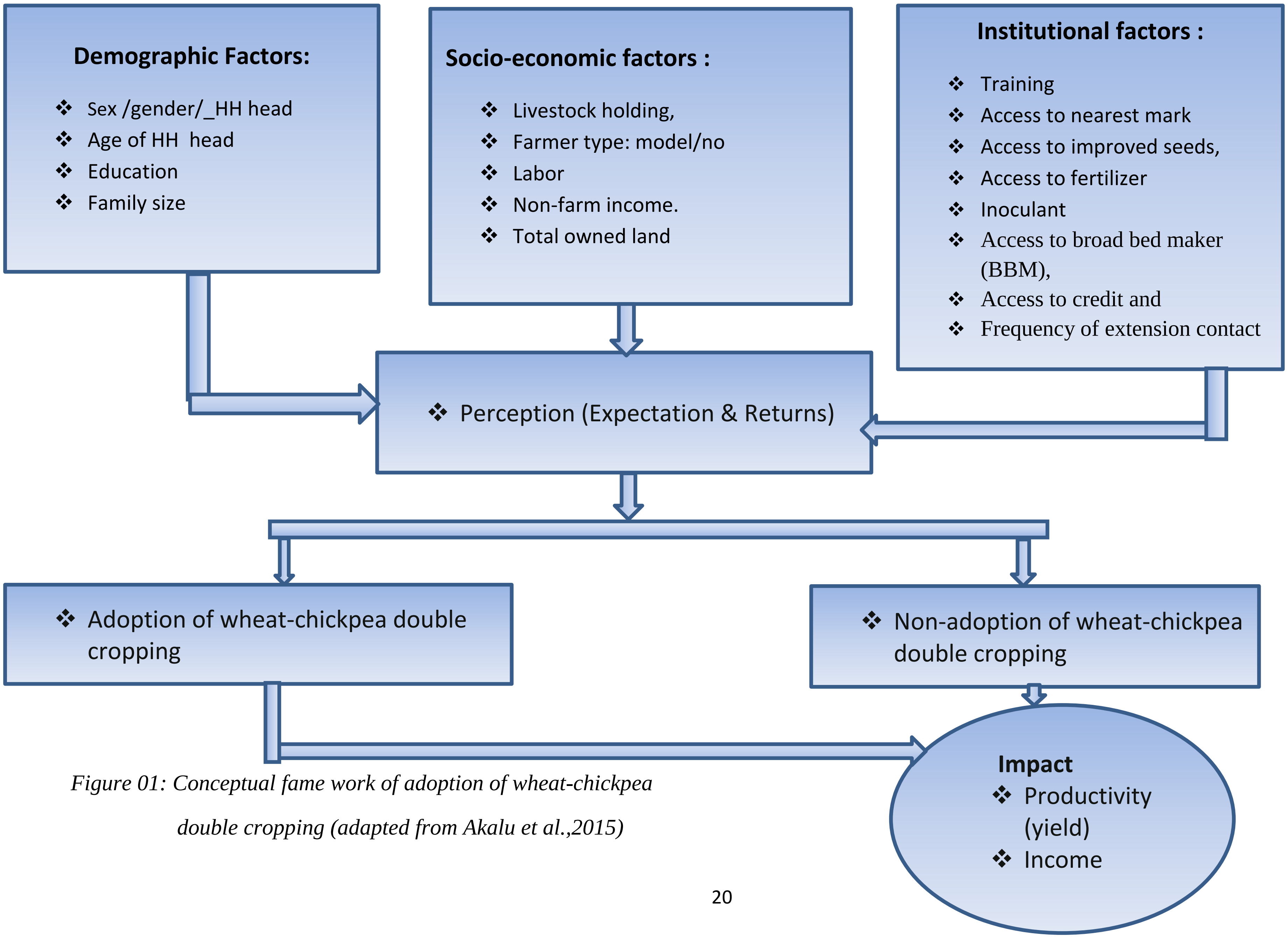

Figure 01: Conceptual fame work of adoption of wheat-chickpea double cropping (adapted from Akalu et al.,2015)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Description of the study area

Becho is the woreda located in the southwest of Shoa; Oromia region. There are 21 kebeles in the woreda, 19 of these kebeles are rural, while the other two are regarded as urban. The woreda is bordered by a number of woredas—in the south it is bordered by Sadden Sodo, to the west by Walisona Goro, to the northwest by Dawo, in the north by Elu, and in the east by Tole woreda. It is located about 80 kilometres (km) southwest of Addis Ababa at 8035’0’’ N and 38015’ 0’’ E latitude and longitude respectively. The woreda is dominated by highlands (roughly 95%), while the remaining area is categorized as mid high lands. The mean annual temperature of the woreda ranges from 16 0^{C} to 25 0^{C} and the mean annual rainfall is about 1,300 millimetres (mm). The main rainy season extends from May to September. Vertisol (black soil) is the main soil type found in the woreda, accounting for about 85% of the soils there and is moderately fertile. This is followed by red soils (10%)—the remaining areas comprise other types of soils. Total land area of the woreda is roughly 44,775 hectares (ha) of which 32,432 ha can be cultivated, and 587 ha can be considered uncultivable. Based on the 2007 national census, Becho had a projected total population of 88,550 people in 2016, 80.4% of them are rural residents. The livelihood of Becho woreda residents is categorized as mixed farming, and the main economic activities are crop and livestock production. The major crops produced in rural Becho are teff, wheat and chickpeas. Becho has a black cotton soil with very low permeability (CSA, 2007, Eyasu, & Van Beek, 2015; CASCAPE, 2015,)

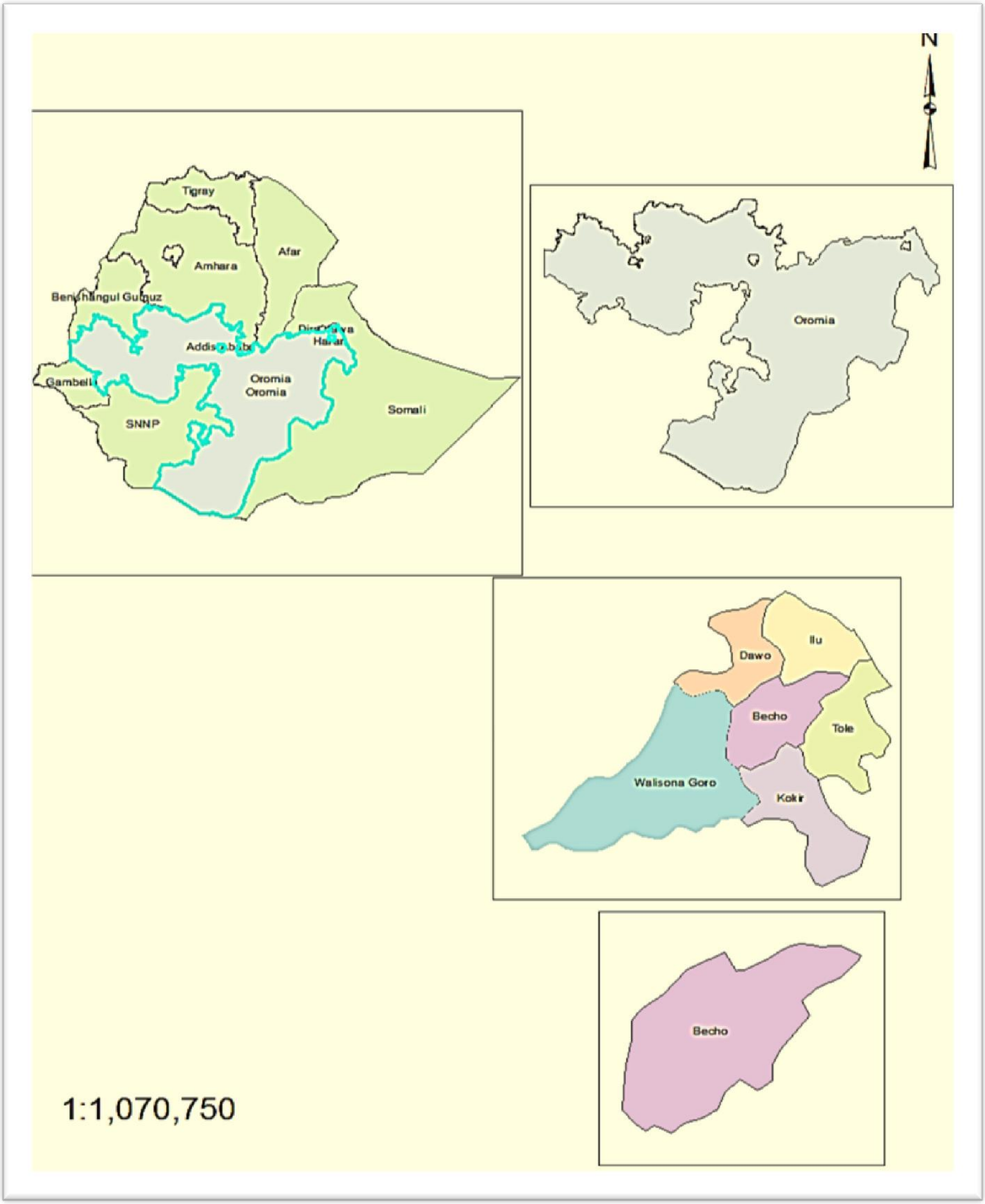

Figure: 02. Map of Becho and its bordering districts-South West Shewa

3.2. Research design and data collection tools

A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. Decisions regarding what, where, when, how much, by what means concerning an inquiry or a research study constitute a research design (Kothari, 2004).

The study made use of Quantitative dominant and qualitative minor, research methods (mixed approach). This design is selected in order to utilize the best of both quantitative and qualitative designs in one. Using combination of both approaches provides a more complete understanding of research problem than either approach alone. Hence, to better investigate the problem and to collect sufficient relevant information, both quantitative and qualitative approaches were used. Hence, data collected through both approaches were triangulated, analyzed and reported. In order to collect relevant sufficient data questionnaire and focus group discussion were employed. Questionnaire was used for quantitative data; while, Focus Group Discussion (FGD) to collect qualitative data. One focused group discussion was conducted in the meeting hall of Becho woreda office of agriculture with the support of the focal person of agricultural growth person /AGP/. Audio recording was made based on the consent of the eight farmers. The focused group discussion had composition of two, two farmers from each of the four target kebeles consisting of one model and one non-model farmer per kebele.

To address the research questions, different explanatory variables are considered on which basis, the data was collected: which are Age, gender(sex), education, livestock holding, non-farm income, labor, family size, farm land holding size, training (knowledge and skill of the HH head), access to early maturing improved seeds, access to credit, bio-fertilizer (Rhizobium bacteria), access to broad bed maker (BBM), access to nearest market, access to fertilizer, frequency of extension contact and farmer type were collected from primary sources (i.e. sample farmers).

3.3. Sources of data

This study utilized both primary and secondary sources in order to collect valid and reliable data. Primary data was collected through formal farm house hold survey. The household survey was conducted through semi-structured questionnaires and FGD from the sample rural farm households in Becho woreda. In the course of collecting data from the primary sources both the questionnaires and FGD were conducted using randomly selected informants from the farmers' households. The data collected is generally based on the adoption of wheat – chickpea double cropping with its determinant factors and impacts on yield and farm income.

Secondary sources of information were various document analyses related to the topic under discussion. In this regard, the following sources of secondary data were visited with serious care and precaution. These include: official documents, printed statistical evidences, published sources, unpublished sources, and etc.

3.4. Population, samples and sampling techniques

The woreda is selected as a target study site due to the fact that, the rain fall distribution combined with the high retention of Vertisol accounting for about 85% of the soils of the woreda, enables the area to support two crops of high compatibility; wheat under full rain fall and chickpea on residual moisture.

This study categorizes the survey population at two levels, namely at the rural kebele level and at the farm household level. A two-stage stratified random sampling method was employed to draw representative sample respondents. In the first stage, rural kebele administrations were stratified into two categories as potential and less potential wheat and chickpea growers. Accordingly, among the numerous Vertisol dominant kebeles in the woreda, four potential wheat and chickpea producing kebeles were selected using simple random sampling.

In the second stage, sample households from each kebele were stratified (probability sampling) into two groups based on their adoption status as adopters and non-adopters of wheat- chickpea double cropping. As it is indicated below, based on Yamane's (1967: 886) sample size determination formula a total of 203 households were considered.

Finally, the survey was administered and data was collected and analyzed on 203 respondent households. This is purposed to easily assess status of adoption of double cropping of wheat with chickpea than mono cropping, also factors affecting adoption of the same and it is impact on yield and farm income were assessed. The sample size is determined using Yamane (1967: 886) sample size determination formula.

i.e.

$$n = \frac{N}{1+N(e)^2}$$

Where *n* is the HH level sample size, *N* is the population size. Based on the 2007 national census, Becho had a projected total population of 88,550 people in its 21 kebeles in 2016. Among these, 80.4% of them are rural residents in 19 kebeles with the projected population of 71,194. The remaining two (2) kebeles are urban constituting 10.6% with the projected population of 17,356 people. According Becho woreda office of agriculture, the average house hold size in the locality is 6 (The study also proved the average family size in the worea to be 6.44, with minimum 1 and maximum 13); the quotient of N to the average HH size gives us 11,866. For this sample size determination, *e* is the level of precision. It is considered to take 0.07 as a value of precision.

$$\text{Hence,} \quad n = \frac{11,866}{1+11,866\,(0.07)^2} = 203$$

Therefore, the sample size for this this study, based on Yamane, ((1967: 886) is 203 respondent households. In cases where large sample size could not be collected due to finance, Kothari, (2004; 175) states, "In practice, size of the sample depends upon the amount of money available for the study purposes. This factor should be kept in view while determining the size of sample for large samples result in increasing the cost of sampling estimates." At 95% confidence level, which has 5% precision, the sample size would have been too big as more than 350. As unit of analysis for this study is at the household level of the four kebeles (strata), 7% precision level is taken to increase homogeneity within adoption stratum and heterogeneity between strata.

For the sake of existing samples in different strata (four different Kebeles in the woreda), based on the total 203 sample size, Kotharis proportional sampling method is applied. According to Kothari,(2004), "The method of proportional allocation under which the sizes of the samples from the different strata are kept proportional to the sizes of the strata. That is, if Pi represents the proportion of population included in stratum i, and n represents the total sample size, the number of elements selected from stratum i is (n. Pi). Where, Pi=quotient of actual population of the specific kebele divided by the total population of the four kebeles.

With this procedure, finally, the survey was administered and data were collected and analyzed on 203 respondents. The number of respondents in each rural kebele is shown in Table 1 below.

Table 1: Proportional sampling of the four Kebeles (strata)

No. of strata	Name of the Kebeles	Population=N (Household)	Proportional sample (Household)
Kebele-1	Awash Bune	1023	77
Kebele-2	Soyama	673	51
Kebele-3	Baballi	530	40
Kebele-4	Batu	459	35
Total		2685	203

3.5. Procedures of data collection

Based on the nature of the problem understudy, basic questions were developed in light of the general and specific objectives of the study. Detailed literature review was made in a broad independent chapter. And then, data collection tools were prepared in a complete form and tested by pilot test inventory. The Pilot test was made to recheck appropriateness, validity and reliability of the instruments. Based on the suggestions forwarded on the pilot test, data collection instruments were improved and necessary correction were made by avoiding ambiguous words and simplifying difficult terms for ease of understanding before the instruments were administered to the sampled respondents of the study. The questionnaire, (translated to the local language _ Oromiffa) was verbally interviewed and the FGD guide was used to make the focused discussion. Twelve enumerators (woreda level agricultural experts and Kebele level development agents (DAs) were trained and deployed for data collection.

3.6. Methods of data analysis

This study employed both descriptive statistical tools and non-linear econometric model (i.e. binomial probit model and propensity score matching method) for data analysis.

3.6.1. **Descriptive analysis**

This study employed descriptive statistical tools such as; percentage, mean, SD, chi2, T-test, minimum and maximum values to roughly analyze adoption status before the detail econometric analysis of wheat and chickpea adoption of double cropping in the study area.

3.6.2. Econometric analysis

Binary probit model was employed for econometric analysis of adoption of wheat –chickpea double cropping, and propensity score matching (Psmatch2) for evaluating the impact of adoption on yield and farm income.

3.6.2.1. Probability of adoption

Kothari (2004: 342) states, "If there is a cause-effect relationship between two or more variables (i.e. bivariate or multivariate), regression is the relevant technique for analysis." Adoption of wheat and chickpea double cropping has a cause-effect relationship with different explanatory variables indicated, such as; age of the HH head, gender of the HH head, education level of the HH head, total family size of the HH head, livestock holding, non-farm income, labor, training on double cropping, (farmers' knowledge and skill about practice of double cropping), access to credit, access to improved seeds (early maturing variety), bio-inoculant (Rhizobium), access to broad bed maker (BBM), access to market, access to fertilizer, owned farm size, family size, farmer type (model/non-model farmer).

Since the dependent variable, which is adoption of wheat- chickpea double cropping is binary in nature, it is impossible to employ linear regression. That is because, it has its own limitation but can be overcome by using probit or logit models which work for non-linear regression model and which actually is binary (Belay, 2017; 21). Such models have been widely used in different adoption studies not only to help in assessing the effects of various factors that influence the adoption of a given technology, but also to provide the predicted probabilities of adoption (Asfaw *et al*., 1997). Feder *et al*. (1985) pointed out that both models have been used interchangeably and give almost the same results. To explain the behavior of dichotomous dependent variable it requires to use a suitably chosen cumulative distribution function (CDF). The estimating model that emerges from normal CDF is popularly known as the Probit model (Gujarati, 1995). The probit function is related to the standard normal probability density function, whereas the logit function follows the logistic cumulative distribution function (Berhanu & Swinton, 2003; Guijarati 2004; Mignouna *et al*., 2011).

This thesis used the probit adoption model to analyze households' adoption decision on wheat-chickpea double cropping in Becho woreda. This is because it is the appropriate econometric model for the binary dependent variable and the error term is normally distributed. The probit model assumed that households make adoption decisions based on the objective of maximizing utility. In brief terms, the decision of a household (in this case an adopter) to adopt the wheat-chickpea double cropping (Yi=1) or not (Yi=0) depends on an unobservable utility index (also known as a latent variable), that is determined by one or more explanatory variables, Xi.

The Probit model is specified as:

$$Y_i = \beta_0 + X_i \beta_i + \varepsilon_i$$

Where i= 1, 2, 3…..n (1)

Where: Y_i is a dummy variable indicating the probability of adoption and related as:

Y_i = 1 if $Y_i > 0$, otherwise Y_i= 0

β_0 = intercept

X_i - is household characteristics of variables that determining farmers adoption in the probit Model.

β_i - is unknown parameter to be estimated in the probit regression model.

The empirical model is specified as:

Adoption of wheat-chickpea double cropping = β_0 + β1age + β2gender + β3education+ β4farmer type + β5total family size + β6labor+ β7owned land holding + β8involvement in non-farm income + β9Tot TLU +

$\beta10$training on double cropping + $\beta11$access to improved seeds + $\beta12$access to broad bed maker (BBM) + $\beta13$ access to fertilizer+ $\beta14$access to market + $\beta15$ access to credit+ $\beta16$ Bio-fertilizer (Inoculant) +$\beta17$frequency of extension contact +ei

The assumption is that, the error term ei is independent of the explanatory variables included in the model.

3.6.2.2. Impacts of adoption

The purpose here is mainly to estimate the impact of adopting the double cropping technology on the life of adopters in comparison to those households who are non-adopters. This could be seen in terms of yield and farm income.

In reality, farmers are not randomly assigned into the treatment and control groups (i.e. the choice of adopting wheat - chickpea double cropping is not random by its nature). This means that the probability of a given farm household to fall in a treatment or control category depends, among others, on the personal and farm characteristic of that household. Thus, it is crucial to take care of this potential selectivity bias/ SB /.

One approach to control for such potential selection bias is to use the propensity score matching (psmatch2) method. This method was first suggested by Rosenbaum and Rubin (1983), and in the recent literature, it became a common impact evaluation tool (Kassie et al., 2009).

The main purpose of using the PSM (psmatch2) method is to find a group of non-treated farmers (those who did not adopt the double cropping technology) similar to the treated groups (adopters of the double cropping technology) in all relevant observable characteristics with the only difference being one group adopts and the other group does not. That is to say, with matching methods, one tries to develop a counterfactual or control group that is as similar to the treatment group in terms of observed characteristics. The idea is to find, from a large group of non-participants, individuals who are observationally similar to participants in terms of characteristics not affected by the program. Each participant /treated group/ is matched with observationally similar non-participant/control or comparison group/ and then, the average difference in outcome across the two groups is compared to get the program treatment effect.

The propensity score matching approach captures the effects of different observed covariates *X* on participation in a single propensity score or index. Then, outcomes of participating and non-participating households with similar propensity scores /common support/ are compared to obtain the program effect. Households for which no match is found are dropped /off support/ because no basis exists for comparison.

It is possible to identify welfare effect of adopting double cropping technology on the outcome of interest (yield per hectare and income in birr) from the following equation:

$$\mathbf{E\ [Y_1\text{-}Y_0 \mid \mathit{D}=1]=\mathit{E}\ [Y_1 \mid \mathit{D}=1]\text{-}\ \mathit{E[Y_0} \mid \mathit{D}=1]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where, Y is yield per hectare (say, in quintals or in birr) and D takes the value 1 for adopters (treatment group) and 0 for non-adopters (control group). Thus, the outcome of interest is the average difference in Y1 and Y0. However, this matching exercise tries to estimate only; $\boldsymbol{E[Y_0 \mid D=1]}$, which is the counterfactual or the unobservable case, since one farmer falls only in one state (either in the treatment group or in the control group) at a time. In our case, this means, trying to estimate the impact of being an adopter on yield per hectare for those farmers who are actually in the control group.

For experimental data in which the farmers are randomly assigned to the treatment and control groups, it would have been possible to estimate the average treatment effect (ATE) as:

$$\boldsymbol{ATE=E\ [Y_1 \mid D=1]\text{-}\ E[Y_0 \mid D=0]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

However, this study relies only on observational data, not experimental. And hence, instead of ATE, the issue of interest for this study is average treatment effect on the treated (ATT); based on Rosenbaum and Rubin (1983) to solve the selection bias by estimating the following equation:

$$\mathbf{E\ [Y_1\text{-}Y_0 \mid \mathit{Z, D}=1] =\mathit{E}\ [Y_1 \mid \mathit{Z, D} =1] - \mathit{E}\ [Y_0 \mid \mathit{Z, D}= 1]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where, Z is set of covariates which determine the adoption status of farmers. If the probability of being an adopter is determined by Z, then it is possible to establish a control group of non -adaptors that are similar in Z relative to adopters (the treatment group). Thus, from equation (3), it is possible to estimate the Average Treatment effect on the Treated (ATT) as:

$$\boldsymbol{ATT = E\ [Y_1\text{-}Y_0 \mid P\ (Z), D=1] =E\ [Y_1 \mid P,(Z), D =1] - E\ [\ Y_0 \mid P(Z), D= 0]} \ldots\ldots\ldots\ldots\ldots 4$$

where P(Z) is the probability of selection conditional on Z or it is the propensity score (Pscore) which is: P(Z) $\equiv Pr(D = 1 \mid Z)$.

Hence, the matching is done using psmatch2 in two stages. First, the propensity scores (P-scores) are calculated using stata's "pscore" command. The Pscores are the conditional probabilities that a given farmer adopting the double cropping technology. Calculating the propensity score is crucial since it is difficult to do the matching on each explanatory variable when there are many covariates. The main purpose of the propensity score estimation is to balance the observed distribution of covariates across the two groups. Matching test was also conducted after matching to check whether or not the differences in covariates in the two groups in the matched sample have been eliminated. Finally good matching quality was achieved. In the second stage, the average treatment effect on the treated (ATT) was estimated using psmatch2. Robustness of the ATT found by using psmatch2 was also checked by running matching algorithms such as the nearest neighbor (NN), kernel and stratification matching techniques. Psmatch2 is selected due to the fact that it estimates both propensity score and ATT by itself.

3.7. Variables definition and hypothesis

A. Dependent variable

Adoption of wheat - chickpea double cropping: is the dependent variable for the probit analysis, and is dichotomous. Hence, it has exactly two values, i.e. 1 and 0, where 1 stands for respondents (farmers) who have adopted the double cropping of wheat and chickpea; while 0 denotes non- adopters.

Outcome variables:

i. Yield (quintal/hectare):

Yield (quintal/hectare): is the first outcome variable and it is about status of yield advantage farmer households get by adopting the double cropping technology. It is continuous outcome variable measured in terms of Q/ha. Although wheat and chickpea are commodities of interest in the double cropping study, yield advantage comparison was made on the crop that both adopters and non-adopters cultivate. That is wheat. Hence, this outcome variable is about the status of yield advantage possibly earned by adopters (treated) due to decision they made to adopt wheat-chickpea double cropping in comparison to the non-adopters (controls). The hypothesis is that, the value of the coefficient (β) for yield increase to be different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with yield increase of wheat in Q/ha over the non-adopters.

ii. Farm income:

Farm income: is the other outcome variable and it is about amount of annual farm income earned by household farmer by adopting the double cropping technology. It is continuous outcome variable measured in terms of birr. The farm income obtained from both production of wheat and chickpea for the treated, (since they adopt wheat and chickpea double cropping) and only wheat for the controls (since they are mono croppers or non-adopters) will be considered because, double cropping is the focus of the study. The hypothesis is that, the value of the coefficient (β) for farm income to be different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with farm income of wheat and chickpea.

B. Independent Variables

There are seventeen independent variables that are assumed to affect adoption of wheat and chickpea double cropping technology. These are: Age, gender, education, farmer type, livestock holding, non-farm income, family size, labor, owned farm land holding, training on double cropping, access to improved seeds, access to fertilizer, access to credit, access to market, bio-inoculant (inoculant), access to broad bed maker (BBM) and frequency of extension contact.

The independent (explanatory) variables are defined as follow:

Age of the household head: Age is one of the factors assumed to affect adoption of new agricultural technologies. It is a continuous variable and is measured in years. Young farmers are more likely to adopt new technologies than the older farmers, because they may have more schooling than older farmers and have been exposed to new ideas and hence more risk takers (Assefa and Gezahegn, 2010). Hence, it is expected that, age of the household head is positively related to the adoption of wheat-chick pea double cropping.

Gender (sex) of the HH head: Gender is also one of the different other factor assumed to affect adoption of agricultural technology**.** It is a dummy independent variable indicating sex of the household head and is measured as binary variable; 1=Male, 0=Female. Female headed households are not likely to adopt new technology due to many factors as compared to their male counterpart (Yemane, 2014*)*. The hypothesis therefore is, male farmers are more likely to adopt wheat-chickpea double cropping.

Education level of the HH head: Education is also one of the other factor assumed to affect adoption of agricultural technology**.** It is a dummy variable measured in terms of 1= can read and write, 0 =cannot read and write. It is expected that, education of the household head is positively related to the adoption of wheat-chick pea double cropping. According to Regasa, (2016) Education is one of the many factors that positively affect agricultural technology adoption in a manner that it may enhance the efficiency of adoption decisions.

Farmer type (model or non-model farmer): is dummy variable and is measured in terms of 1= model farmer or 0= non model farmer. Hence, the hypothesis is that the value of the coefficient (β) for farmer type is different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable.

Total family size: It is a continuous variable and is measured in terms of number of individuals living in one family. The more the family size grows, the more the demand for food will be. So as to meet the growing family's demand for food, it requires to cultivate more crops on a given limited farm land. This will be possible by adopting double cropping and be able to harvest twice in a given one season. By doing so, one contributes to food security. Hence, it is hypothesized that the value of the coefficient for household size is different from zero and adoption of double cropping of wheat and chickpea has a significant positive relationship with family size. Household who has many active family labour, the probability of technology adoption also increase positively (Negera and Getachew, 2014).

Labor: is about availability of enough labor force to provide required support in the farming practice. It is dummy explanatory variable measured in terms of 1= yes, 0= no. The hypothesis is that, the value of the coefficient (β) for active labor force availability to be different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable; availability of labor force. Fabiyi (2015) states that, house hold size affected adoption of agricultural technologies positively and significantly. But, Shaw, (2014) states that, the availability of labor does not significantly impact modern agricultural technology adoption decisions.

Farm size (Owned farm land holding): is continuous independent variable measured in terms of hectare. It is expected that, the value of the coefficient for house hold's farm land holding size to be different from zero, and adoption of double cropping to have a significant negative relationship with farm size. That is to say, the smaller the land size is, the higher would be the probability of adoption rate. Samuel et al (2017) states, Farm size influences adoption of agricultural technologies negatively and significantly.

Non-farm income: is a binary independent variable and is measured in terms of (1= yes or 0=otherwise). It is assumed to have a positive relationship with adoption of wheat-chickpea double cropping. That is due to the fact that, non-farm income adds value to the financial capacity of the smallholder farmers to have easy access to technological inputs, such as improved seeds, improved broad bed maker (BBM) and the likes; as the cost of agricultural inputs are increasing. Hence, it is expected that the value of the coefficient for non-farm income to be different from zero and adoption of double cropping to have a significant positive relationship with non-farm income. Hassen *et al.,* (2012) states, the more off/non-farm income, the farmer generates, the higher he/she resolves his/her financial constraints and the faster to adopt.

Livestock holding: It is a continuous explanatory variable measured in tropical livestock Unit (TLU). According to Storck et al., (1991) Tropical Livestock units are livestock numbers converted to common unit. TLU equivalent conversion factors are: Calf = 0.20, Heifer & Bull= 0.75, Cows & Oxen =1, Camel =1.25, Horse/Mule =1.10, Donkey =0.70, Sheep & Goat= 0.13, Chicken/poultry 0.013. A household with large livestock holding can obtain more cash income from the sales of animal products. This income in turn helps smallholder farmers to purchase farm inputs. It is expected the value of the coefficient for livestock holding to be different from zero and adoption of double cropping to have a significant positive relationship with livestock holding. Hence, livestock ownership is hypothesized to be positively related to the adoption of wheat-chickpea double cropping. The study conducted by Sisay (2016) states, livestock holding influences adoption of agricultural technologies positively and significantly.

Training on double cropping: It is about status of the household head's exposure to trainings regarding importance and practice of double cropping of wheat and chickpea. It is dummy variable and measured as binary variable (1=If trained or skilled, 0= otherwise) and is assumed to have a positive relationship with the dependent variable. Therefore, the hypothesis is that, the value of the coefficient (β) for the independent variable which is; status of farmers' knowledge and skill about importance of double cropping is different from zero and the dependent variable which is; adoption of the double cropping has a significant positive relationship with the independent variable that is status of farmers' knowledge and skill (training). That is to say, the trained farmers are hypothesized to be good adopters and those who are not trained (not knowledgeable) about the same are hypothesized to be none adopters of the double cropping. Galmesa, (2018) states that, training influences adoption of agricultural technologies positively and significantly.

Access to improved seeds: is the provision of research released improved varieties of the target crops that mature in shorter time compared to the local variety. Thus, it is measured in terms of accessing the improved crops or not. Therefore, it is a dummy variable and expected to have a positive relationship with the dependent variable. Hence, the hypothesis is that the value of the coefficient (β) for access to early maturing improved seeds is different from zero and adoption of what and chickpea double cropping has a significant positive relationship with the explanatory variable. That is to say, the more the access to improved varieties is, the more will be adoption of the same. According to the study conducted by Regasa,(2016) timely availability of improved high yielding varieties influences adoption of agricultural technologies positively and significantly.

Access to Broad Bed Maker (BBM):is the usage of the broad bed maker (BBM) technology to drain excess water from the water logged Vertisol. Thus, it is measured in terms of 1= have access to BBM or 0= otherwise. Therefore, it is a dummy variable and expected to have a positive relationship with the dependent variable. Hence, the hypothesis is that the value of the coefficient (β) for use of BBM technology is different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable; which is access to BBM. According to CASCAPE-AAU,(2015) Innovation of agricultural technology such as BBM created an opportunity for the farmers to efficiently utilize their farm land and increase production and productivity through draining excess water from vertisol soil which was the major challenge for the majority of wheat producing farmers in Becho area.

Access to fertilizer: is a dummy variable and is measured as; 1=have access or 0= otherwise. Hence, the hypothesis is that, the value of the coefficient (β) for access to fertilizer is different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable; which is access to fertilizer. Regasa, (2016) states that, timely availability of fertilizer influences adoption of agricultural technologies positively and significantly.

Access to nearest market: is a dummy variable and is measured as; 1=have access or 0= otherwise. Hence, the hypothesis is that, the value of the coefficient (β) for access to nearest market is different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable; which is access to nearest market. According to study conducted by Kinyangy, (2014) market availability has a positive and significant ($p<0.05$) influence on adoption of agricultural technology.

Access to credit: is about availability of credit services to the farmers during their needy time to purchase farm inputs and is measured as; 1=yes, 2=No, 3=Medium and 4=I have my own and no need to take credit. Hence, the hypothesis is that, the value of the coefficient (β) for access to credit is different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable; which is access to credit. Mesfin, (2017) states, Credit access have significantly influence on adoption of agricultural technologies.

Bio-inoculant (Rhizobium): is about level of availability (shortage) of the right strain of rhizobium bacteria for the purpose of inoculation; so as to help the legume - chickpea fix atmospheric nitrogen. Thus, it is measured as binary variable; 1= yes, there is shortage, 0=otherwise. Hence, the hypothesis is that the value of the coefficient (β) is different from zero and adoption of wheat and chickpea double cropping has a significant negative relationship with the explanatory variable. It is expected that access to inoculant increases probability of adoption (shortage decreases probability of adoption) of the technology of double cropping. Mesfin,(2017) states, availability of bio-inoculant have 13% share of relative importance in influencing farmers' decision to adopt.

Frequency of extension contact: Is about frequency of the extension agents visit made to the farmers to provide technical support. It is therefore a continuous variable measured in days. The hypothesis is that, the value of the coefficient (β) for frequency of extension contact to be different from zero and adoption of wheat and chickpea double cropping has a significant positive relationship with the explanatory variable; frequency of extension contact. Sisay (2016) also found that the frequency of extension contact has a significant positive effect on adoption of agricultural technologies.

Table 02: Summary of explanatory variables

Variables	**Type of variable**	**Expected sign**	**Unit of measurement**
Sex /Gender/ of the HH head	dummy	+	1 = M, 0 = F
Age of the HH head	continuous	+	years
Education /Able to read & write?/	dummy	+	1=Yes, 0=No
Farmer type: model/non model	dummy	+	1=model, 0=non model
Total family size	continuous	+	Number
Labor	dummy	+	(1=Yes, 0=No)
Owned farm size	continuous	-	hectare
Non-farm income involvement	dummy	+	1= Yes, 0 = No
Livestock holding	continuous	+	TLU
Training attendance on DC	dummy	+	1=yes , 0= not taken
Access to improved seeds	dummy	+	1= have access,0= no access
Access to broad bed maker (BBM)	dummy	+	1= have access, 0= otherwise.
Access to fertilizer	1, 2 ,3	+	1= Yes, 2=No access 3=Medium
Access to nearest market	dummy	+	1= have access, 0= otherwise
Access to credit	1,2,3,4	+	1= Yes, 2=No 3=Medium 4=I have my own and no need of credit
Bio fertilizer (shortage)	dummy	-	1= yes, 0 =otherwise
Frequency of extension contact	continuous	+	days

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents major findings of the study. To this effect, both descriptive and inferential statistics were used to analyze the primary data. Cross sectional primary data was collected from both adopters and non-adopters of wheat –chickpea double cropping in the South West Showa zone of Becho woreda's sampled four rural kebeles named; Awash Bune, Baballi, Batu and Soyama.

Descriptive statistics were used to describe the general demographic, socio-economic and institutional characteristics of wheat-chickpea double cropping in the study area. Besides, econometric or inferential statistics (Probit model and Psmatch2) were employed to identify factors affecting adoption of the double cropping technology and its impact on yield and farm income respectively.

4.1. Descriptive results

Descriptive statistics such as frequency, percentage, chi^2, t-test, mean, standard deviations, minimum and maximum values were used to describe the demographic, socio-economic, and institutional characteristics of the sampled households in adoption study of wheat chickpea double cropping. Statistical t test and X^2-test comparison of variables expected to determine relationship between the dependent variable and each of the explanatory variable for the adoption study of wheat-chickpea double cropping in the target woreda.

4.1.1. Demographic characteristics of the households

From the entire two hundred and three (203) sampled households interviewed, majority of sample respondents, about 189 (93.1%) were male headed and 14 (6.9%) were female headed respondents. On average, the chi-square test of sex distribution between the adopters and non-adopters was found to be statistically insignificant at X^2 (1, N=203)=0.17, Pr=0.68). And this shows that, there is no significant relationship between sex of adopters and non-adopters of wheat chickpea double cropping. In support of this, Regasa, (2016) during his study on adoption and impact of high yielding wheat varieties on farm income; states that, "No significant difference is observed in the sex of household head since almost all of the respondents were male headed households."

With regards to education status (ability to read and write), from the entire sampled households interviewed, about 58 (69.9%) of adopters responded 'Yes' to education (ability to read and write) while 25(30.1%) responded 'No'. On the other hand, 31(25.8%) of non-adopters responded 'Yes' to ability to read and write, while the larger proportion of non - adopters 89(74.3%) responded 'No'. The chi-square test result showed that, there is significant relationship(dependence) between education and the dependent variable which is adoption at 1% confidence level; X^2 (1, N=203)= 38.661 Pr = 0.000. That means, there is dependence between educational status of the households and the propensity to participate in adoption of wheat-chickpea double cropping.

Table 3: Sex and education status (ability to read and write) of sample households

Variables		Adopters (N=83)		Non- adopters (N=120)		Total (N=203)		
		No	%	No	%	x^2-test	No	(%)
Sex	Male	78	94	111	92.5	0.17	189	93.1
	Female	5	6	9	7.5		14	6.9
Education	Yes	58	69.9	31	25.8	38.66	89	43.8
	No	25	30.1	89	74.2		114	56.2

Pearson chi^2(1) = 0.17 Pr = 0.683 ; Pearson chi^2 (1) = 38.661 Pr= 0. 000 (Source: Own survey result, 2019)

With regards to age of the total respondents, the average age of the adopters and non-adopters was 44.5 and 42.2 years, respectively. The t-test of age between adopters and non-adopters was found to be insignificant at calculated T =1.57 and tabulated T =.1. 97 (DF=201; Pr (|T| > |t|) = 0.1172. That means, there is no statistically significant mean difference between ages of adopters and non-adopters. Galmesa, (2018) in his survey work on adoption of improved soya bean varieties; stated that, "The t-test of age between adopters and non-adopters was found to be insignificant. That means there is no statistical mean difference between adopters and non-adopters in terms of age"

With regards to family size of the total respondents, the average family size of the adopters was 6.89 people and while it is about 6.14 persons for non-adopters. On average, the total sample households have about 6.44 family size with minimum of 1 and maximum of 13. The t-test of family size between adopters and non-adopters was found to be significant at 5% significance level, with calculated T= 2.47, tabulated-T= 1.96; which is greater than T-calculated. Here, Pr(|T| > |t|) = 0.0140. As null hypothesis assumes there is no mean difference; this gives us evidence to reject the null hypothesis and accept the alternative hypothesis; as there is statistically significant mean difference between family size of adopters and non-adopters. Here, adopters average family size is by far greater than average family size of non-adopters .

Table 4: Age and family size of sample households

Variables	Adopter (N=83)		Non-adopters (N=120)		t-test
	mean	Std	Mean	Std	
Age	44.5	9.23	42.2	10.71	1.57
Family size	6.89	1.96	6.14	2.22	2.47 **

** represents 5% significance level. (Source: Own survey result, 2019).

4.1.2. Socio economic status of the households

With regards to owned farm size of the total 203 respondents, the survey results showed that the households' cultivable farm land possession ranged from the smallest 0.5 ha to the highest 7.0 ha. The average size of cultivable land owned by the sample respondents was about 2.73 ha for adopters' households and 2.17 ha for the non-adopters. The t-test distribution of owned farm size between adopters and non-adopters was found to be significant at 1% confidence level, with calculated T= 3.35, tabulated T= 1.973; at Pr(|T| > |t|) = 0.001. This gives us evidence to reject the null hypothesis and accept the alternative hypothesis; as there is significant mean difference between land holding size of adopters and non-adopters. Here, adopters' average owned farm size is bigger than that of the non-adopters households.

Table 5: Owned land holding of sample households

Variables	Adopter (N=83)		Non-adopters (N=120)		t-test
	mean	Std	Mean	Std	
Owned land holding	2.73	1.25	2.18	1.08	3.35 ***

*** represents 1% significance level (Source: Own survey result, 2019).

The following figure shows graphical presentation of the total land holding status of both adopters and the non-adopters in Becho woreda.

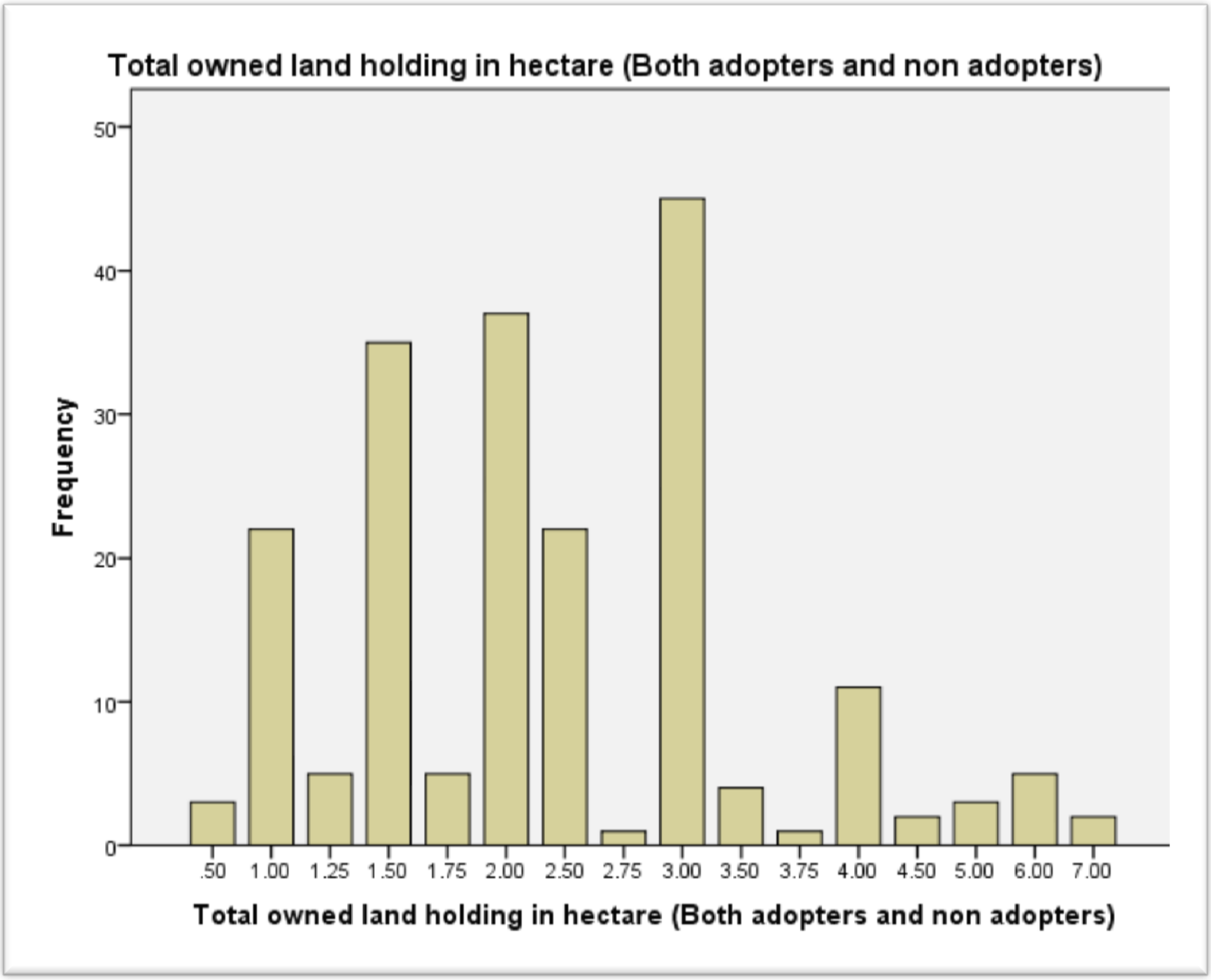

Figure: 03. Total owned land in hectare_ both adopters and non-adopters
(Source: Own survey result, 2019)

In line with adopters' land allocation to wheat-chickpea double cropping, the following figure shows how small proportion of their land adopters allocated to the double cropping compared to the total land they owned. From the average 2.73 hectare cultivable land owned by the 83 adopters, out of the total 203 respondents, the average land they allocated for wheat-chickpea double cropping in the year 2009/10 Eth.C or (2017/18G.C.) was only 0.3 hectare at standard deviation of 0.45. Specifically, 10 adopters allocated the minimum 0.25 ha., 67 adopters allocated 0.5-1.0 ha., 5 adopters allocated 1.25-2.0 ha. The final 1 adopter allocated the maximum 2.5ha. (Minimum 0.25 and maximum 2.5ha).Result of the study shows that, apart from encouraging the non-adopters to adopt the technology, it requires a lot to address the determinant factors and encourage adopters themselves in making them allocate good size of their land for double cropping and make more benefit from the cropping system. The focused group discussion /FGD/ participant farmers indicated that, majority of the farmers allocate larger proportion of their land for cultivation of teff mono cropping which is basically staple food crop but very low yielding compared to both wheat and chickpea.

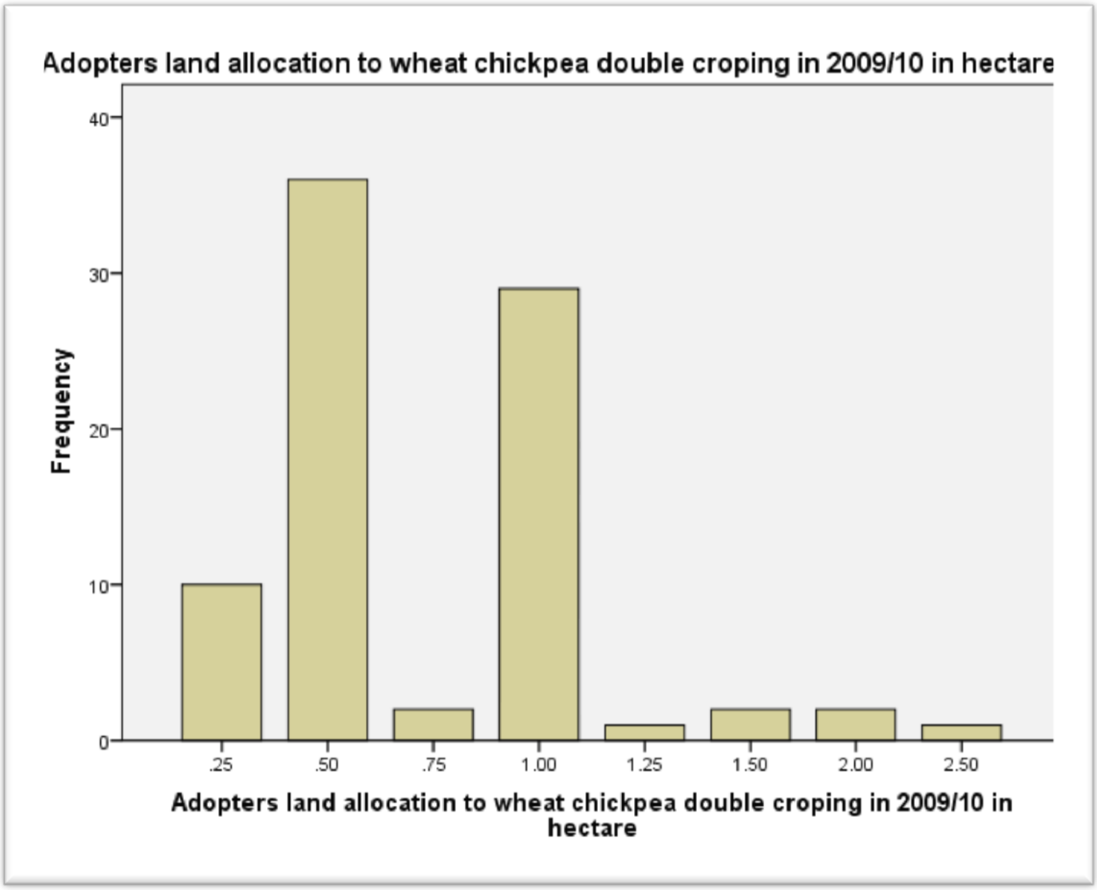

Figure: 04. Status of adopters' land allocation to wheat-chickpea double cropping.
(Source: Own survey result, 2019)

With regards to livestock holding measured in tropical livestock unit (TLU) of the total respondents, the average livestock holding of the adopters was 6.23 TLU and it is 3.98 TLU for the non-adopters. On average, the total sample households have about 4.9 tropical livestock unit. The tropical livestock unit was strongly and statistically significant difference between adopters and non-adopters of the sample households. The t-test distribution for livestock holding (TLU) between adopters and non-adopters was found to be significant at 1% confidence level, with calculated T= 4.39, tabulated T= 1.973; at Pr(|T| > |t|) = 0.0000. This gives us evidence to reject the null hypothesis and accept the alternative hypothesis; as there is significant mean difference between livestock holding (TLU) of adopters and non-adopters.

With regards to non-farm income of the total respondents, the average non-farm income of the adopters is 7645.8 birr and it is 10239.3 birr per annum for the non-adopters. On average, the total sample households earn 8942.55 birr per annum. The t-test distribution for non-farm income between adopters and non-adopters was found to be insignificant at calculated T= 1.0053 and tabulated T= 1.973; at Pr(|T| > |t|) = 0.3195. This gives us evidence to accept the null hypothesis and reject the alternative hypothesis; as there is no statistically significant mean difference between non-farm income earnings of adopters and non-adopters per annum.

Table 6: Livestock holding (TLU) and non-farm income of sample households

Variables	Adopter (N=83)		Non-adopters (N=120)		t-test
	mean	Std.	Mean	Std.	
Livestock holding (TLU)	6.23	4.469	3.98	2.79	4.39***
non-farm income	7645.8	10109.69	10239.3	7920.75	1.0053

*** represents 1% significance level (Source: Own survey result, 2019).

With regards to respondents category as model and non-model (farmer type), out of the total respondents, 42 (50.6%) of adopters are found model farmers, while, 41(49.4%) are non-model farmers. On the other hand, 7(5.8%) of non-adopters are found model farmers while, 113 (94.2%) of them are found non-model. Becho woreda office of agriculture uses farmer type categorization as motivation tool to encourage ‘’B and ‘C’ level farmers to become model farmer who are in ‘A’ category in adopting useful technologies such as double cropping. The ‘A’ level model farmers have good recognition at the woreda, zone and regional level. The chi-square test showed that, there is significant association (dependence) at 1% confidence level between adoption and farmer type (model and non-model category) at X^2 (1, N=203)= 53.7025 Pr = 0.000. Here, larger proportion of adopters is model farmers.

With regards to labor availability, out of the total respondents, 66 (79.5%) of adopters responded ‘Yes’ to shortage of labor; and 17(20.5%) responded ‘No’. The former have labor problem and the later do not. On the other hand, 73(60.8%) of the non-adopters responded ‘Yes’ to labor shortage and the remaining non-adopters 47(39.2%) responded ‘No’ to shortage of labor; which means that they have good availability to labor. The chi-square test showed that, there is significant association at 1% confidence level between labor and adoption of the double cropping at X^2 (1, N=203)= 7.935 Pr = 0.005.

Table 7 Farmers type and labor availability of sample households

Variables		Adopters (N=83)		Non- adopters (N=120)		Total (N=203)		
		No.	%	No.	%	x^2-test	No.	(%)
Farmer type	Model	42	50.6	7	5.8	53.7	49	24.1
	Non-model	41	49.4	113	94.2		154	75.9
Labor	Yes	66	79.5	73	60.8	7.935	139	68.5
	No	47	39.2	17	20.5		64	31.5

Pearson $chi^2(1)$ = 53.7025 Pr = 0.000; Pearson $chi^2(1)$ = 7.935 Pr = 0.005

(Source: Own survey result, 2019)

4.1.3. Institutional factors

In line with status of formal training given to the respondents on double cropping of wheat and chickpea, out of the total respondents, 79 (95.2%) of adopters responded ‘Yes’ while, 4(4.8%) responded ‘No’. On the other hand, 26(21.7%) of non-adopters responded ‘yes’ while, 94 (78.3%) of them responded ‘No’ or are found untrained on double cropping of wheat and chickpea. non-model. The chi-square test showed that, there is significant association (dependence) between adoption and training at X^2 (1, N=203)= 106.1893, Pr = 0.000). Here, it can be seen that, those who are trained are more adopters than the untrained ones who are found non-adopters.

In line with status of access to improved seeds of wheat and chickpea, out of the total respondents, 72 (86.7%) of adopters responded ‘Yes’ while, 9(10.8%) responded ‘No’, On the other hand, 12(10.0%) of non-adopters responded ‘yes’ while, 108 (90.0%) of them responded ‘No’. The chi-square test showed that, there is strong significant association between adoption and access to improved seeds at 1% significance level, at X^2 (3, N=203)= 126.07 Pr = 0.000). Here, adopters are found to have better access to improved seeds while larger proportion of non-adopters are found to have very less access to improved seed. Here, it can be seen that, access to improved seed can be considered as limiting factor to adoption to double cropping of wheat and chickpea (see table 8 below).

In line with status of shortage of bio-fertilizer (inoculant/rhizobium),out of the total respondents, 43 (51.8%) of adopters responded ‘no’ to shortage, while, 19(22.9%) responded ‘yes’, to shortage, 21(25.3) responded “Medium” On the other hand, 24(20%) of non-adopters responded ‘no’ to shortage, while, 78(65%) of the non-adopters responded “Yes” to shortage and the remaining non adopters 15(18%) responded ‘Medium’ to shortage of bio fertilizer(inoculant). The chi-square test showed that, there is significant association between adoption and access to bio fertilizer/inoculant/ at 1% confidence level, at X^2 (2, N=203)= 35.95 Pr = 0.000).

Table 8: Training on DC, access to improved seeds and bio-fertilizer/inoculant/ of sample households.

Variables		Adopters (N=83)		Non-adopters (N=120)		Total (N=203)		
		No	%	No.	%	x^2-test	No.	(%)
Training given	Yes	79	95.2	26	21.7	106.18	105	51.7
	No	4	4.8	94	78.3		98	48.3
Access to improved seeds	Yes	74	89.2	12	10	126.07	43	21.2
	No	9	10.8	108	90		68	33.5
Bio-fertilizer (Inoculant)	Yes	43	51.8	0	0	35.95	43	21.2
	No	19	22.9	120	100		139	68.5
	Medium	21	25.3	0	0		21	10.3

Pearson $chi^2(1)$ = 106.1893 Pr = 0.000, Pearson $chi^2(3)$ = 3.0502 Pr = 0.384, Pearson $chi^2(2)$ = 126.07 Pr = 0.000, Pearson $chi^2(2)$ = 35.95 Pr = 0.000 (Source: Own survey result, 2019)

In line with status of access to fertilizer, out of the total respondents, 82(98.8%) of adopters responded 'Yes' for access to fertilizer while,1(1.2%) responded 'medium' and 0(0%) responded 'No' to the access to fertilizer. On the other hand, 117(97.5%) of non-adopters responded 'yes' for access to fertilizer; while, 2 (1.7%) of them responded 'No' and 1(0.8%) of them responded medium to the access to fertilizer. The chi-square test showed that, there is no significant association between adoption and access to fertilizer at X^2 (2, N=203)= 1.4605 Pr = 0.482.).

In line with status of access to broad bed maker (BBM), out of the total respondents, 76(91.6%) of adopters responded 'Yes' for access to broad bed maker (BBM) while, 7(8.4%) responded 'No' to access to fertilizer. On the other hand, 19(15.8%) of non-adopters responded 'yes' for access to BBM; while, 101 (84.2%) of them responded 'No' to the access to BBM. The chi-square test showed that, there is significant association (dependence) between adoption and access to BBM at 1% confidence level at X^2 (1, N=203) = 113.026 Pr = 0.000).

In line with status of access to market, out of the total respondents, 68 (81.9%) of adopters responded "Yes" to access to market, 15(18.1%) of adopters responded 'No' to the access to market. On the other hand, 40(33.3%) of non-adopters responded "Yes", 80 (66.%) of them responded "No" to the access to market. The chi-square test showed that, there is significant association between adoption and access to market at 5% significance level at X^2 (1, N=203) = 46.53, Pr = 0.00).

In line with status of access to credit, out of the total respondents, 63(75.9%) of adopters responded 'Yes' for access to credit while, 9(10.8%) responded 'No' and the remaining 8(9.6%) of adopters responded 'Medium' to access to credit. On the other hand, 101(84.2%) of non-adopters responded 'Yes' to access to credit, 10(8.3%) of them responded 'No' to access to credit. The remaining 5(4.2%) of non-adopters responded 'No' to access to credit. . The chi-square test showed that, there is no significant association between adoption and access to credit at X^2 (3, N=203) = 3.05 Pr = 0.384).

Table 9: Access to fertilizers, access to broad bed maker (BBM) and access to market of sample households.

Variables		Adopters (N=83)		Non- adopters (N=120)		Total (N=203)		
		No.	%	No.	%	x^2-test	No.	(%)
Access to fertilizer	Yes	82	98.8	117	97.5	1.46	199	98
	No	0	0	2	1.7		2	1.0
	Medium	1	1.2	1	0.8		2	1.0
Access to broad bed maker (BBM)	Yes	76	91.6	19	15.8	113.026	95	46.8
	No	7	8.4	101	84.2		108	53.2
Access to market	Yes	68	81.9	40	33.3	46.53	108	53.2
	No	15	18.1	80	66.7		95	46.8
Access to credit	Yes	63	75.9	101	84.2	3.05	164	80.8
	No	9	10.8	10	8.3		19	9.4
	Medium	8	9.6	5	4.2		13	6.4
	I have money, no need of credit	3	3.6	4	3.3		7	3.4

Pearson chi^2(2) = 1.4605 Pr =0.482, Pearson chi^2(1) =113.02 Pr =0.000, Pearson chi^2(1) = 46.53 Pr =0.000 ; Pearson chi^2(3) =3.05 Pr =0.384 (Source: Own survey result, 2019)

Agricultural extension services provided to farmers from woreda level SMS and kebele level DAs is believed to be of vital importance with regards to access to inputs, training on improved farming practices and access to new technologies. It is widely accepted that considerable productivity increase could be achieved when farmers get appropriate extension services from DAs at the kebele and subject matter specialists (SMS) at the woreda level. The FGD discussion comprising eight farmers from the four Kebeles in Becho woreda revealed that,DAs have been with them almost every day and their issue is support they need from woreda level subject matter specialists(SMS). To this effect, the survey result showed that, out of the total respondents, 1(1.2%) of adopters responded that SMS visit them none a week, 11(13.3%) responded that SMS visit them days in a week, 36(43.4%) responded that SMS visit days in two weeks, 26(31.3%) responded that SMS visit in three weeks or a month, 9(10.8%) responded that SMS visit them only once, in two months or more. On the other hand, 6(5.0%) of non-adopters responded that SMS visit them none in a week, 2(1.7%)

responded that SMS visit them days in a week, 26 (21.7%) responded that SMS visit them days in two weeks, 67(55.8%) responded that SMS visit them in three weeks or in a month,19 (15.8%) responded that SMS visit them only once in two months or more. This indicates that adopters had a better frequency of SMS (extension contact) than non-adopters. The chi-square test showed that, there is significant difference between adoption and extension agent (SMS) visit at 1% significance level at X^2 (4, N=203)= 27.2223 Pr = 0.000).

Table 10: Extension contact (SMS) of sample households.

Variables		Adopters (N=83)		Non-adopters (N=120)		Total (N=203)		
		No.	%	No.	%	x^2-test	No.	(%)
Extension agents' (SMS) visit	None in a week	1	1.2	6	5.0	27.2	7	3.4
	Days in a week	11	13.3	2	1.7		13	6.4
	Days in two weeks	36	43.4	26	21.7		62	30.5
	In three weeks or a month	26	31.3	67	55.8		93	45.8
	Only once in two months or more	9	10.8	19	15.8		28	13.8

Pearson $chi^2(4)$ = 27.2223 Pr = 0.000 (Source: Own survey result, 2019

4.1.4. Adoption status and farmers perception on wheat-chickpea double cropping

Out of the total 203 respondents, 83(40.9%) of them were found adopters and the remaining larger proportion 120 (59.1) of them were found non-adopters of wheat-chickpea double cropping (at mean value of 0.41, std. dev., 0.49 and variance of 0.24 which is square root of the former); in Becho woreda (Figure 5, below).

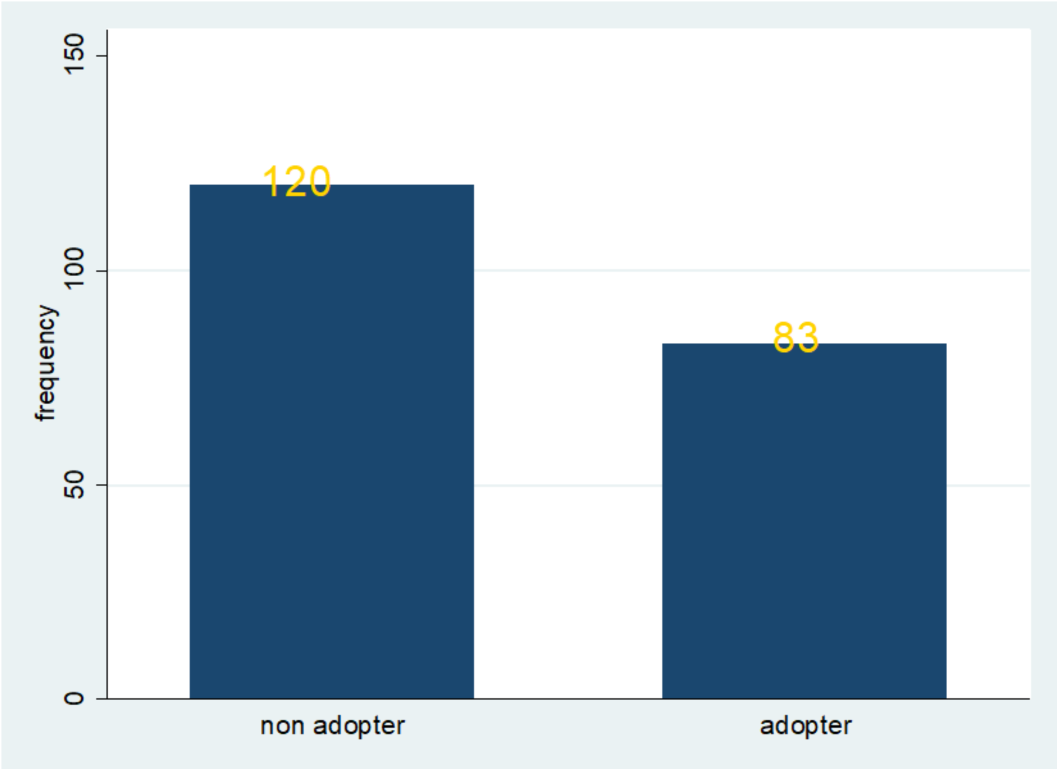

Fig 5: Adoption status of wheat-chickpea double cropping _83 adopters and 120 non adopters. (Source: Own survey result, 2019)

The focus group discussion /FGD/ participants from the four kebeles of the woreda indicated that, adoption status/rate/ of wheat-chickpea double cropping is increasing year to year at lower rate. They indicated that, the low level of land allocation to the double cropping compared to the mono cropping is due to the lack of training (fear of risk taking). The farmers indicated that, if not for the skill and knowledge from the model farmers, majority would not have conducted it due to big lack of training on double cropping.

In connection with this, for the question the total respondents were asked about their perception of double cropping, 85 (41.9%) of them who are labeled blue in the pie graph below, responded "I know it, it increases yield and improves soil fertility." On the other hand, the larger proportion 106(52.2%) of them who are labeled responded "It is not much clear).The remaining 12(5.9%) of them who are labeled grey responded "I don't know it so far." From the piegraph, it is easy to see that, a lot remains to be done so as to scale out the double cropping technology through efficient training (awareness creation and skill development).

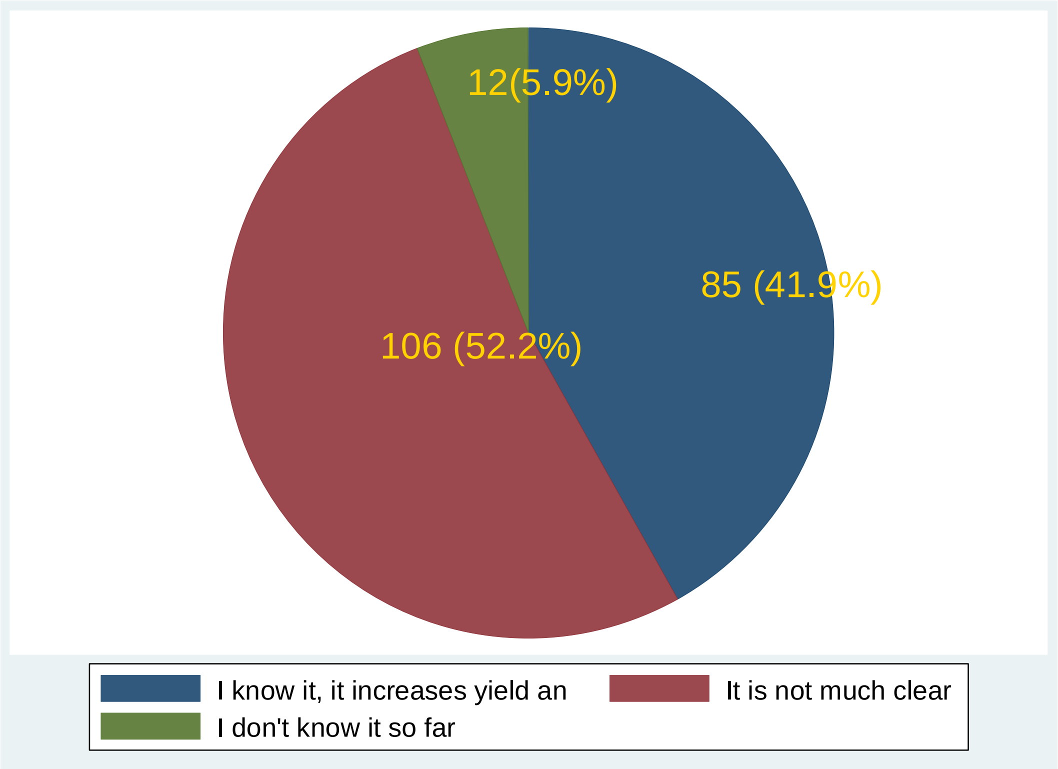

Figure: 06. Farmers' perception on double cropping of wheat and chickpea(Source: Own survey result, 2019)

Hence, during the focused group discussion /FGD/ the farmers capitalized on more organized quality training so as to help them make more use of the double cropping advantage, and to attract more other non-adopters in to the cropping system.

4.2. Econometric results

4.2.1. Goodness of fit to the model/gof/

According to Kothari (2004: 251), the measure of goodness-of-fit used in the binary choice model is the pseudo-R^2. Hence, the chi-square ($\chi 2$) distribution was used as the measure of overall significance of a model in probit model estimation. The pseudo R^2 is 0.8260 and is interpreted as 82.60% of the dependent variable (i.e. adoption of wheat and chickpea double cropping) are explained by the explanatory variables. And, the unexplained part (i.e. 17.4%) is expected to go for un-captured information. The results indicate that, the model has good explanatory power by 82.60%. The model had a log pseudo likelihood of (-23.8959) after fifth iteration. The Wald chi2 test statistics with 17 degree of freedom is equal to 80.49. Prob

> chi2 = 0.0000 is used to test the dependence of the adoption of wheat-chickpea double cropping on the selected independent variables in the model.

4.2.2. Test for Multi-collinearity

The independent variables used in this study were checked for the existence of multi-collinearity and the degree of association using the contingency coefficients test (CCT). The values of contingency coefficient ranges between 0 and 1, with zero indicating no association between the variables and values close to 1 indicating a high degree of association accordingly, the results of the computation reveal that there was no problem of association among the explanatory variables since the result shows as it is below 0.75. (See appendix for CCT table)

4.2.3. Factors affecting adoption of wheat-chickpea double cropping.

The results of Probit model regression showed that, out of the seventeen explanatory variables included in the model, eight have statistically significant effects on the adoption of wheat-chickpea double cropping on the sample respondents. The result showed that sex of household, farmer type (model or non-model), involvement in non-farm income, total owned tropical livestock unit (TLU), training on double cropping, access to improved seeds, access to broad bed maker (BBM) and access to fertilizer are significant factors affecting the likelihood of adoption of wheat-chickpea double cropping.

The model outputs showed that sex of household has a positive influence on the households' adoption decision of wheat-chickpea double cropping at 5 % significance level. This is in agreement with the hypothesis formulated regarding the relationship between gender and adoption of wheat-chickpea double cropping. That is to say, the probability of male respondents to adopt wheat-chickpea double cropping is higher than those of the female respondents at 5% significance level. The marginal effect for sex (gender) is 0.1231 and it implies that other things kept constant *(citrus paribus)*, being male headed household increases the probability of decision to adopt wheat-chickpea double cropping by 12.3% compared to the female headed households (Table,11 below). This is consistent with the result of Shaw, (2014) in his study states, "The gender of the household head was statistically significant and positively related to adoption, that men were more likely to adopt the new agricultural technology than women." Besides, Female-headed households are usually less likely to adopt improved agricultural technology and to apply the recommended agronomic practices since they are usually endowed with less resource and less exposed to new information due to their social position (Namwata et al., 2010; Assefa and Gezahegn, 2010;as cited in Regasa,(2016).

Farmer type /model, non-model/: Farmers are categorized as model and non-model farmers in the study area and other parts of the country. The model farmers are known by their features in taking risks, in looking for new technology that may enhance their productivity. The result of the probit model found out that, farmer type is the other limiting factor which has positive and very significant influence to farmers' decision to adopt wheat-chickpea double cropping at statistically 1% level of significance. This is in agreement with the hypothesis formulated regarding the relationship between farmer type and adoption of wheat-chickpea double cropping. (Table, 11 below).The more the farmers are in model category, the more likely they will be to adopt the technology in comparison to those who are non-model farmers. The marginal effect for farmer type is 0.0951. It implies that, other independent variables kept constant *(citrus paribus),* being a model farmer increases probability of adopting wheat-chickpea double cropping by 9.5% compared to the non-model. During the focused group discussion /FGD/ carried out among the eight farmers from the four kebeles of the woreda, farmers pointed out that, model farmers are by far adopting wheat-chickpea double cropping, compared to the non-model farmers in comparison to the majority of the non-model who are engaged on mono cropping. The farmers indicated that, model ones are working as eye openers to those who are non-model, by trying new innovations such as double cropping introduced in the locality.

Involvement in non-farm activities: Many farmers can earn additional income by engaging in various non-farm income generating activities. The result of the probit model regarding involvement in non-farm activities was found to be in contrary with what was expected. Thus, the null hypothesis is rejected and the alternative hypothesis is accepted. To this effect, it can be concluded that, involvement in non-farm activities have a negative and significant influence to farmers' decision to adopt the technology of double cropping at statistically 1% significance level. That is to say, the probability of farming households engaged in non-farm activities is highly less likely to adopt wheat-chickpea double cropping compared to those who are not engaged in non-farm activities. This can be due to the fact that, they spend much of their time on non-farm activities and less of their time on agricultural works compared to farmer households who are fully engaged in agricultural works as a base of their livelihood. The marginal effect for involvement in non-farm income is -0.0665 and it implies that other things kept constant *(citrus paribus)*, involving in non-farm income decreases farmers decision to adopt double cropping of wheat and chickpea by 6.65% compared to those who do not engage in non-farm activities.(Table,11 below). Chomba,(2004) states, "Framers' involvement in non-farm income has negative and significant relationship with adoption of agricultural technologies"

Total Tropical Livestock Unit /TLU/: The sample households are distinguishable in terms of asset holdings, whereby adopters own more assets in terms of tropical livestock unit. This is the other limiting factor to adoption of wheat-chickpea double cropping in the study area. The probit result showed that, TLU asset ownership has positive and statistically significant influence on adoption of wheat-chickpea double cropping at 5% level of significance. This is in agreement with the hypothesis formulated regarding the relationship between total tropical livestock unit /TLU/ ownership and adoption of wheat-chickpea double cropping in the study area. Here, the probability of farmer households who have more TLU is highly likely to adopt wheat-chickpea double cropping technology at 5%significance level compared to those who have less unit of TLU ownership. The marginal effect for total TLU is 0.00735 and it implies that other things kept constant *(citrus paribus)*, a unit increase in tropical livestock, increases the probability of farmer households decision to adopt wheat-chickpea double cropping by 0.75% (Table,11 below). This is consistent with the result of Hailu (2008), Solomon et al. (2011), Hassen et al. (2012) and Leake and Adam (2015) ;as cited in Ragasa,(2016) found positive relation between livestock ownerships with adoption of agricultural technologies. However, Negera and Getachew (2014) reported that livestock ownership has negative and significant relationship with the adoption of agricultural technologies.

Table 11:Estimated results of Probit model: Likelihood of adoption of wheat chickpea double cropping

Explanatory variables: **Adoption of wheat-chickpea double cropping**	**Coefficient**	**Robust Std. Err**	**Marginal Effects (dy/dx)**
Sex of household head (1=male; 0=female)	1.778**	0.8519	0.1231
Age of household head (years)	-0.012	0.0135	-0.0008
Education /Able to read & write?/ (1=Yes, 0=No)	0.2259	0.3757	0.0156
Farmer type (1=model farmer, 0=non-model)	1.3742***	0.4870	0.0951
Total family size of the household (Number)	-0.0958	0.07627	-0.0066
Labor (1=Yes, 0=No)	0.14246	0.34024	0.0098
Owned land in (Hectare)	-0.06275	0.1952	-0.0043
Involvement in non-farm income (1=Yes, 0=No)	-0.9612***	0.2666	-0.0665
Tropical Livestock Unit (TLU)	0.1062**	0.0417	0.00735
Training on double cropping(1=Yes, 0=No)	2.2736***	0.5963	0.1573
Access to improved seeds (1=Yes, 0=No)	1.9219***	0.3414	0.1330
Access to broad bed maker (BBM) (1=Yes, 0=No)	1.00178**	0.4231	0.0693
Access to fertilizer (1=Yes, 0=No)	1.0311*	0.5850	0.0713
Bio-fertilizer (inoculant) (1=Yes, 0=No)	-0.00046	0.2177	-0.00003
Access to market (1=Yes, 0=No)	0.5503	0.3911	0.0380
Access to credit (1=Yes, 0=No)	0.0097	0.1773	0.00067
Frequency of extension contact (days)	0.1371	0.20124	0.00948
Constant	-6.1764***	1.7907	

Number of observation: 203 Wald chi^2 (17) = 82.49

Prob > chi^2 = 0.0000 Pseudo R^2 = 0.8260

Log pseudo likelihood = -23.895936

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*, ** and *** indicates significant at 10 %, 5%, and 1 % significance levels, respectively

Source: Own survey, (2019)

Training as a capacity development activity is one of the means by which farmers acquire new knowledge and skill and it is of vital importance for farmers so as to help them capacitated with the required knowledge and skills. The more they are capacitated with the required need based knowledge and skills, they will be enabled to produce more, improve their livelihood and will have higher probability to achieve better quality of life. Hence, the probit model result showed that, training has positive and statistically strongly influence to farmers' decision to adopt wheat-chickpea double copping in the study area at 1% level of significance. The result of probit regression indicated that, farmers who took part in double cropping training are more likely to adopt wheat-chickpea double cropping technology at 1% significance level compared to those who are not trained on the double cropping technology. This is in agreement with the hypothesis formulated regarding the relationship between training and adoption of wheat-chickpea double cropping in the study area. The marginal effect for training on double cropping is 0.1573. This implies that, other things kept constant *(citrus paribus)*, being trained on double cropping increases probability of adoption of wheat-chickpea double cropping by 15.7% compared to the farmer households who are not trained on double cropping. Please, see table (11) above. This is in line with previous studies such as; Alemitu, (2011), Hadush (2015) and Wuletaw and Daniel (2015) as cited in Gelmesa, (2018) stated, "Training influences adoption of adoption of new technology positively. Farmers who participated in training have higher probability of adoption of new technologies (Wuletaw and Daniel, 2015) Participants of the focused group discussion clearly indicate that, they lack well organized training on double cropping technology. From the eight farmers who took part in the FGD, it is found out that, only one farmer from Awash Bune kebele took training on double cropping of wheat and chick pea. The remaining farmers from the other kebels, namely; Baballi, Soyama, Batu and the other representative from Awash Bune itself did not take training on double cropping technology.

Access to improved seeds (wheat and chickpea): For double cropping technology to properly and smoothly function, access to improved seeds that are early maturing are too vital in rained situation such as Becho, the study woreda. This is because, the main season crop such as wheat need to leave the plot as early as possible for the subsequent crop chickpea leaving behind residual moisture enough for chickpea to grow and perform better. The probit model result showed that, access to improved seeds has positive and statistically strongly significant influence to farmers' adoption of wheat-chickpea double cropping at 1% level of significance. As indicated in the table above, the result of probit regression indicated that, farmers who have good access to improved seeds were found to have higher probability of adoption of wheat-chickpea double cropping compared to those who have no good access to improved seeds of the target commodities. This is in agreement with the hypothesis formulated regarding the relationship between access to improved seeds and adoption of wheat-chickpea double cropping in the study area. The marginal effect for access to improved seeds of wheat and chickpea double cropping is 0.1330. This implies that, other independent variables kept constant *(citrus paribus),* getting access to improved seeds increases probability of farmer households' decision to adopt the double cropping by 13.3% compared to those who have no access to improved seeds.The farmers participants in the focus group discussion capitalized that, Ararti and Habru are well performing early maturing chickpea varieties in practice in Becho woreda. With regards to the early maturing wheat varieties identified by the farmers during the focused group discussion, Kakaba and Hidase are capitalized as the well performing early maturing varieties highly suitable for double cropping in Becho woreda. They indicated that, Danda'a is a high yielding variety, but due to its long maturing nature, it does not suit for double cropping. Digalu variety is getting obsolete due to its susceptibility to rust and hence, it is off option. As per the FGD participants, access to early maturing improved seeds is determinant factor to adoption of wheat-chickpea double cropping in the locality.

Broad Bed Maker/ BBM/: Broad bed maker in Becho woreda, which is dominated by Vertisol (soil that has water logging nature), is limiting factor to adoption of wheat-chickpea double cropping. Draining water by using BBM is essential to plant wheat as early as possible during main season to save enough good time for chickpea production in that same production season. Probit regression revealed that, access to BBM has a positive and statistically significant influence to farmers' adoption decision of wheat chickpea double cropping in the study area at 5% significance level. This is in agreement with the hypothesis formulated regarding the relationship between access to BBM and adoption of wheat-chickpea double cropping in the study area. The marginal effect for access to BBM is 0.0693. This implies that, other things kept constant *(citrus paribus),* access to BBM increases probability of farmer households' decision to adopt wheat-chickpea double cropping by 6.93% compared to those farmer households who have no access to BBM. (Table,11 above). Participants of the focused group discussion /FGD/ indicated that, the previous BBM corporately dispatched all across was very heavy for the oxen and the farmers themselves and it is no more being used in the woreda. With regards to the modified "Aybar" BBM, they stated that, it is highly scarce and farmers have no access to it. Hence, majority of them stated that, for their Vertisol dominant soil, they are using rather the local bed maker known as "Shaga". They admitted that, "shaga" is not much of help in making broad bed as the "Aybar" BBM if not for its scarcity. During the FGD, the farmers also added that, access to proper BBM has been a limiting factor for adoption of double cropping of wheat and chickpea in the area.

Access to fertilizer: is the other limiting factor identified in adoption of wheat-chickpea double cropping and it has positive and significant influence only at 10% level of significance to farmers decision to adopt wheat-chickpea double cropping. (Table,11 above). This is in agreement with the hypothesis formulated regarding the relationship between access to fertilizer and adoption of wheat-chickpea double cropping in the study area. The probit regression result found out that, the marginal effect for access to fertilizer is 0.0713. It implies that, other things kept constant *(citrus paribus)*, getting access to fertilizer increases probability of adoption of wheat-chickpea increases by 7.13% compared to the farmer households who have no access to recommended fertilizer (stated Urea amount and recommended amount of Blend fertilizer which is NPSB in the case of Becho). While discussing about access to fertilizer in double cropping practice of cereal with legume, it is good to note that, inoculated chickpea, fixes significant amount of atmospheric nitrogen and by doing so, reduces certain amount of Urea purchase for the cereal. The focused group discussion made for this survey revealed that, inoculated chickpea fully supports itself by fixing atmospheric nitrogen in symbiosis with rhizobia and no synthetic Urea is required to be purchased. This is consistent with studies conducted by Endalkachew, et al., 2018 which stated "In addition to yield advantage, the benefit of chickpea is equivalent to application of 60 kg N/ha as fertilizer, through attractive feature of chickpea in its ability to fix atmospheric nitrogen in symbiosis with rhizobia. By doing so, it directly add value to grain protein and reduces the need for N fertilizer for subsequent crops."

But for the subsequent crop, which can be wheat, the discussion made with the farmers from the four kebeles of the woreda stated that, minimum of 50 kg/ha is reduced due to chickpeas contribution in double cropping of wheat and chickpea. Those who used to apply 150 kg Urea/ha now apply 100 kg/ha and achieving good performance in wheat. Hence, it is a constant that, farmers purchase full recommended amount of blended NPSB (Nitrogen, Phosphate, Sulfur and Boron) in one, in place of the previous blanket recommendation of DAP (Di-Ammonium-Phosphate). Apart from Becho woreda, other certain close by woredas are actually recommended to still use DAP.

The above eight explanatory variables were found to have statistically significant influence on farmers' decision to adopt wheat-chickpea double cropping in the study area. On the other hand, the remaining independent variables were found to have insignificant effect on farmers' decision to adoption of wheat chickpea double cropping in the study area. These were, age of the house hold head, total family size of the house hold, education level of the house hold head, total owned land, inoculant availability, labor availability, access to credit, access to market and frequency of extension contact.

4.2.4. Impact of adoption_ wheat-chickpea double cropping on yield and farm income.

4.2.4.1. Propensity score distribution and matching of treated and control groups.

In the evaluation problems, data often do not come from randomized trials but from non-randomized (which is observational study). Rosenbaum and Rubin (1983) proposed propensity score matching as a method to reduce the bias in the estimation of treatment effects with observational data sets. As the first step in Propensity score matching with psmatch2, is employing pscore command in to STATA and estimating propensity score/likelihood of adoption/ for all treated and controlled households. This was accomplished before launching the matching task as indicated in table 12 below.

Table 12: Distribution of estimated propensity scores for sampled households.

Propensity of participation /Adoption status/	Frequency	Percent
Control/Non-adopters/	120	59.11
Treated /Adopters/	83	40.89
Total	203	100

Source: Own survey,(2019)

Matching of treated and control households was carried out to determine the common support region. The basic criterion for determining the common support region is to discard all off-support observations whose propensity score is smaller than the minimum propensity scores of adopters (treated) and larger than the maximum of the (control group) non-adopters. That is, excluding all observations out of the overlapping region. A common support condition is based on the propensity score distributions of the households with and without the program (adoption of wheat-chickpea double cropping). The common support option has been selected and the balancing property is satisfied in matching individuals with similar observable characteristics with the treated group. Thus, the common support assumption is satisfied in the region of [0.0015934, 0.96334867] for sample households. This means that households with estimated propensity scores less than 0.0015934and greater than 0.96334867 are not considered in the matching undertakings.

As a result of this restriction, in total, 190 sample households (83 treated and 107 controls) were identified to be considered in the estimation process. In the matching process, 13 sample households (0 treated and 13 control sample households) were discarded from the total 203 observations of 83 treated and 120 controls (Table 13 below).

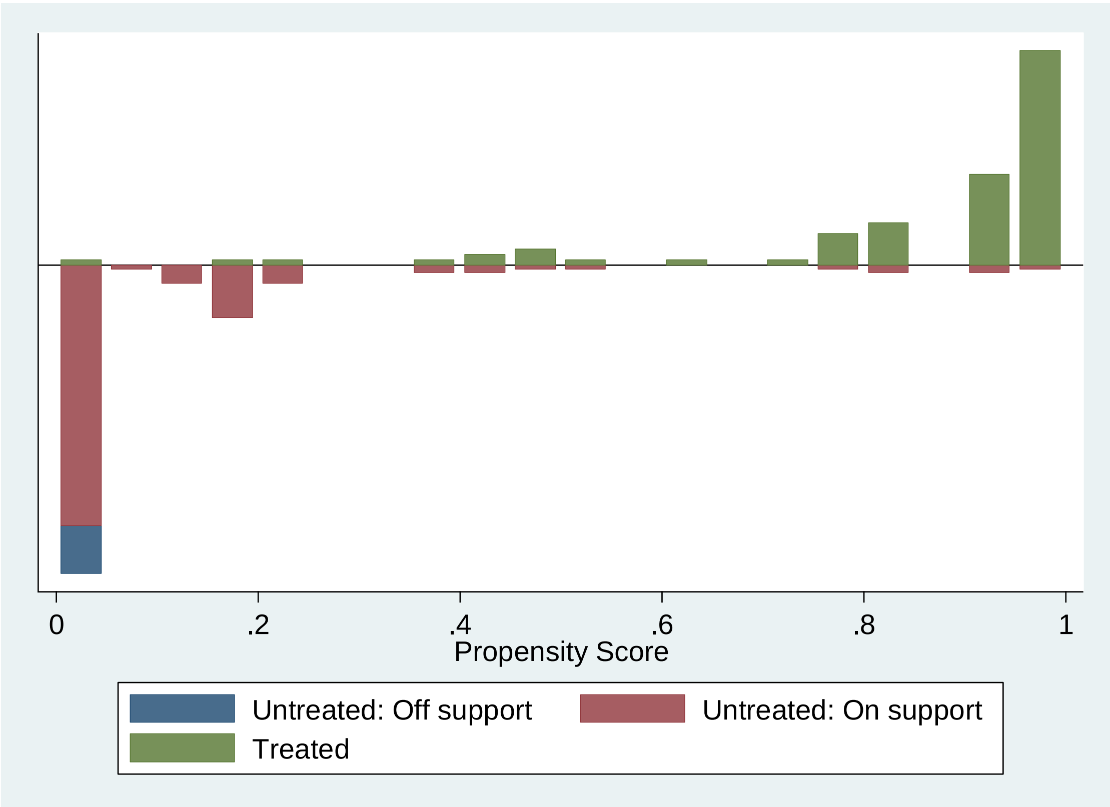

Figure 7: Psgraph
Source: Own survey, (2019)

4.2.4.2. Balancing tests for matching quality

After matching is carried out, it requires checking quality of balance between the observable covariates. To this effect, pstest command in psmatch2 was put to use for calculation of several balancing measures. Pstest calculates balancing status of the variables before and after matching. It is checked considering the standardized % bias, mean bias before and after matching (formulae from Rosenbaum and Rubin, 1985): this should be less than 5% after matching, Ps R^2 to be very close to zero after matching and t-test and p-value (p>chi2) to be non-significant after matching for good matching performance..

After many trials it is managed to find an overall good matching quality as indicated in table 13 below and appendix VII.

All other specifications run with various covariates that showed poor matching quality (mean bias and the other testing measure) were discarded till this good performance level is achieved. Unlike those other tried specifications, for this specification of the pscore model, the mean bias and % bias for the covariates in the specification were successfully managed to be all less than 5% (table 14 below for brief summary and appendix VII for the specific t-test, %bias p-values and summarized matching test table) .To this effect, the overall matching performance is found good: after matching the average mean bias is 2.7, which is much less than 5 but, before matching, it was 119.2; P value was expected to be non-significant for the pstest and hence, after matching it is managed to get it non-significant (0.996). Besides Ps R^2 is expected to be very close to zero after matching, after many trials it is managed to get it in its very required level 0.002 (See table 14 below). It is as the balancing quality is satisfied in such a way that, the ATT result is considered reliable. According to Rosenbaum and Rubin, (1985), balancing check of pstest, as validation activity, confirms reliability of the ATT result run only after good balancing quality is achieved.

Table 13: Pstest summarized output on matching quality

Sample	**Ps R2**	**LR chi2**	**p>chi2**	**Mean Bias**	**Med Bias**	**B**	**R**
Unmatched	0.675	185.38	0.000	119.2	112.4	318.9	0.49
Matched	0.002	0.38	0.996	2.7	3.7	9.5	1.08

Source: Own survey,(2019)

4.2.4.3. Impact of adoption_ ATT_ grain Yield (Q/ha)

Average Treatment Effect on the Treated (ATT)

The estimated average treatment effect (ATT) result of sample households found by using psmatch2 showed that adoption of wheat –chickpea double cropping generated positive and statistically significant wheat yield differences between treated and controlled, measured in quintal per hectare (Q/ha).It is good to note that, wheat is the common crop for both the treated and the controls which suits to estimate yield based ATT of both. Table 14 below shows that, the average treatment effect on the treated (ATT) of wheat yield of adopters and non-adopters for the production year of 2009/10 Eth.C has 6.96 Q/ha difference over the untreated at statistically significant level (where t=3.46). In terms of the average yield (Q/ha) of the treated and the non-treated, the psmatch2 result showed that, treated groups harvested average wheat yield of 21.2 Q/ha ,while the non-treated/ control/ groups harvested average wheat yield of 14.2 Q/ha at statistically significance at (t=3.46). This indicates that, wheat-chickpea double cropping worth adopting. Adopter participants in the focus group discussion /FGD/ indicated that, the practice of double cropping is very useful in a way that it is improving fertility of their soil, is increasing production, productivity and is at same time increasing their income and as a whole is improving their livelihood.

Table 14: psmatch2_ Average Treatment Effect on Treated (ATT)_Yield (Q/ha)

Outcome variable	Sample	Treated	Control	Difference	S.E.	T-stat
Yield *(wheat)*	Unmatched	23.1144	16.525	6.589	0.7786	8.46
	ATT	21.2	14.2	6.96	2.011	3.46

Source: Own survey,(2019)

4.2.4.4. Impact of adoption_ ATT_ farm income (birr/annum)

Average Treatment Effect on the Treated (ATT)

The estimated average treatment effect (ATT) of sample small holder households showed that, adoption of Wheat-chickpea double cropping has strong positive significant effect on farm income too, measured in birr per annum. The ATT result found by using psmatch2 showed that adoption of wheat –chickpea double cropping created on average positive farm income differences between adopters (*wheat and chickpea double croppers*) and non-adopters(*wheat mono croppers*) for the production year of 2009/10 Eth.C. (See table 15 below). The table shows that, the average treatment effect on the treated (ATT) of farm income has 18,564 (Eighteen thousand five hundred sixty four) birr difference over the controls. Here, just like the yield advantage seen above, the treated (adopters) are beneficiaries of economic advantage due to the adoption of wheat-chickpea double cropping at statistically significant level (t=5.34). In line with average annual income of the treated and the non-treated, the psmatch2 result showed that, treated groups earned average annual income of 22,692.8 birr, from sale of both wheat and chickpea as adopters while, the control groups earned average annual income of 4,128.5 birr as mono croppers from sale of wheat only at statistically significance level at (t=5.34). It can be seen that, both the yield and income result favored the treated groups who are adopters of the wheat –chickpea double cropping.

To see how the income difference 18,564 birr is obtained by the treated group, it is good to note that, the study is on double cropping and the farm income comparative assessment is made between the small holder farmers who cultivated both wheat and chickpea in same season on single plot and the non-adopter small holder farmers who cultivated wheat only and leave that single plot without production after harvest of wheat.

Table 15: psmatch2_ Average Treatment Effect (ATT)_Farm income (Birr/annum)

Outcome variable	Sample	Treated	Control	Difference	S.E.	T-stat
Farm income *(wheat and chickpea)* (birr/annum)	Unmatched	26354.04	5087.5	21266.5	1513.32	14.05
	ATT	22,692.8	4128.57	18,564.2	3475.91	5.34

Source: Own survey,(2019)

Hence, the study shows that, the non-adopters lose on two grounds: i) Adopters have better yield advantage on wheat itself with 6.96 Q/ha difference over the non-adopters just by adopting the double cropping (as indicated in yield ATT section). ii) Adopters practice double cropping by immediately planting chickpea on residual moisture after harvesting of wheat on that same plot. The price of chickpea is more expensive than wheat. As per the local market price during the survey data collection time, farmers indicated that wheat was being sold for 1000 -12000 birr/q (one thousand to one thousand and two hundred birr per quintal). On the other hand, local market price of chickpea was 1400-1900 birr/q (one thousand and four hundred to one thousand and nine hundred). Since adopters harvest chickpea in addition to wheat in that same season, on that single plot, they are better off than the non-adopters(*keeping other farm incomes constant*) in generating additional income. In such a way, one can clearly see how adopters managed to earn the average treatment effect of the 18,564 birr difference over the non-adopters.

In line with this, impact assessment conducted by Regasa, (2016) on Adoption and Impact of high yielding wheat varieties, by comparing income from wheat only; confirmed that, the treated households had earned farm income of about 21452 ETB per year with a difference of 10,311 birr per year.

To check robustness of the result, different matching methods such as nearest neighbor matching method (NNM), Kernel matching method (KMM), and stratification matching methods were employed for both outcome variables; namely, yield and farm income as indicated in (Table 16 and 17) below and appendix (X). In general, all the four matching methods revealed that, adopters of wheat-chickpea double cropping have generated significantly higher output (wheat yield Q/ha and farm income birr/annum) compared to the non-adopters households. This suggests that, better wheat production and much better farm income were gained by adopting the double cropping technology; which in turn encourages adoption of the wheat-chickpea double cropping.

Above all matching algorisms, pmatch2 result of both outcome variables was selected as best ATT since it represented much larger matched sample (common support) in comparison to the other matching algorithms, although its ATT result is lower.

Table 16: Performance of matching estimators for sample households (wheat yield in Q/ha)

Matching estimator	Matched sample	ATT (yield)	Bootstrapped Std. err	t-stat
Nearest neighbor matching method	134	9.27	2.19	4.21
Kernel matching method	155	9.3	1.18	7.9
Stratification method	155	9.2	1.45	6.35
Psmatch2	190	6.96	2.01	3.46

Table 17: Performance of matching estimators for sample households (farm income _birr)

Matching estimator	Matched sample	ATT (income)	Bootstrapped Std. err	t-stat
Nearest neighbor matching method	134	22064.76	2304.1	9.57
Kernel matching method	155	22715.45	1961.7	11.5
Stratification method	155	22681.6	2030.7	11.1
Psmatch2	190	18564	3475.9	5.34

Adopters of wheat-chickpea double cropping achieved much better farm income from sale of both wheat and chickpea over the non- adopters who generated much less farm income (keeping other farm incomes constant); only from sale of wheat; which is also of comparatively low yield

4.2.4.5. Sensitivity analysis

According to Dehejia (2002), sensitivity analysis is the final diagnostic that is performed to check the sensitivity of the estimated treatment effect to small changes in the specification of the propensity score; this is a useful diagnostic on the quality of the comparison group. Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. Based on this principle, sensitivity analysis is tested to check whether unobserved covariates have effect on the results by creating biases or not. Furthermore, after ATT is found, it is vital to test whether the estimated ATT results are effective or not. And hence, sensitivity analysis was undertaken to detect the identification of conditional independence assumption (CIA) if it is affected by the confounder or not. Table 18 and 19 below revealed the sensitivity analysis of the outcome ATT values of wheat yield in Q/ha and farm income from wheat and chickpea in the production year of 2009/10 Eth.c to the confounders. The sensitivity analysis result shows that, the significance level of ATT is unaffected and is insensitive to external change. Therefore, the CIA remains to be significant and the results were not sensitive to the confounders and there are no external cofounders (variables) which affect the results calculated for ATT of both outcome variables_ yeld and farm income. Table 18 and 19 below and Appendix (XI & XII) revealed that the sensitivity analysis of the outcome variables' (yield and farm income) technical efficiency. The Gamma values from 1 to 2 has upper significance level of $9.8e\text{-}^{09}$ and lower significance level 0 for wheat yield; $7.9e^{-14}$ and lower significance level 0 for farm income. This result indicates that the technical efficiency is significant or robust and the ATT results of both outcome variables were not sensitive to the confounder.

Table 18: Sensitivity analysis for outcome variable one: Yield (Q/ha _ 2009/10 Eth.C)

Gamma	**σ^+ (sig$^+$)**	**σ^- (Sig$^-$)**
1	3.3e-15	3.3e-15
1.05	1.5e-14	6.7e-16
1.1	5.7e-14	1.1e-16
1.15	2.0e-13	0
1.2	6.1e-13	0
1.25	1.7e-12	0
1.3	4.6e-12	0
1.35	1.1e-11	0
1.4	2.6e-11	0
1.45	5.6e-11	0
1.5	1.2e-10	0
1.55	2.3e-10	0
1.6	4.3e10	0
1.65	7.8e-10	0
1.7	1.4e-09	0
1.75	2.3e-09	0
1.8	3.9e-09	0
1.85	6.2e-09	0
1.9	9.8e-09	0
1.95	1.5e-08	0
2	2.3e-08	0

* gamma - log odds of differential assignment due to unobserved factors
sig+ - upper bound significance level
sig- - lower bound significance level

Table 19: Sensitivity analysis for outcome variable two: Fram income from sale of wheat and chickpea

Gamma	**σ^{+} (sig^{+})**	**σ^{-} (Sig^{-})**
1	1.2e-15	1.1e-15
1.05	5.7e-15	2.2e-16
1.1	2.3e-14	0
1.15	7.9e-14	0
1.2	2.5e13	0
1.25	7.3e-13	0
1.3	2.0e-12	0
1.35	4.8e-12	0
1.4	1.1e-11	0
1.45	2.5e-11	0
1.5	5.2e-11	0
1.55	1.0e-10	0
1.6	2.0e-10	0
1.65	3.6e-10	0
1.7	6.4e-10	0
1.75	1.1e-09	0
1.8	1.8e-09	0
1.85	3.0e-09	0
1.9	4.7e-09	0
1.95	7.3e09	0
2	1.1e-08	0

* gamma - log odds of differential assignment due to unobserved factors

sig+ - upper bound significance level

sig- - lower bound significance level

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

Adoption of wheat –chickpea double cropping is of vital importance for small holder farmers on Vertisol dominant areas for its multifaceted advantages. These are yield increase, soil fertility improvement due to inoculated chickpea's contribution in fixing natural atmospheric nitrogen, opportunity to produce twice in a single season wheat/ *triticum aestiviem*/ in main season and chickpea /*Cicer arietinum L* on residual moisture immediately after wheat is harvested and repeating the same in subsequent year. This gives opportunity to produce more in same season on a single plot without a need for farm expansion in such time of increasing land fragmentation due to booming rural population in Ethiopia. As exposure to produce twice in a year contributes to food security, chickpea being protein rich crop, it contributes to nutrition security. The more the soil health is maintained through naturally activated fertility factor, double cropping contributes to sustainable agricultural system.

This study was initiated to fill the gap of information on factors influencing adoption of wheat-chickpea double cropping, and its impact on yield and farm income of smallholder households in the study area. Cross-sectional data was collected from 203 sample farmer households using a two stage stratified random sampling techniques. The analysis was made using descriptive statistics and econometric model.

On the main features of sampled respondents, comparisons were made using descriptive statistics. Results of the comparison revealed that; adopter sample household farmers have more education, have better access to labor (better off to pay), owned more tropical livestock unit than non-adopters, owned more farm land, were more trained on double cropping, have better access to improved seeds, have better access to bio fertilizer, have better access to broad bed maker and have better access to market. Besides, larger proportions of adopters were model farmers unlike the non-adopters.

Hence, the study addressed factors affecting farmer's decision to adopt the technology. The study identified key factors that influence adoption of wheat-chickpea double cropping in the study area. The variables significantly identified by the probit regression model as affecting factors to adoption of wheat-chickpea double cropping were: sex of the house hold head (probability of male households to adopt the technology is significantly higher than the women), Farmer type (propensity of the model farmers to adopt the technology is higher than the non-model), involvement in non-farm income(has negative and significant influence to adoption), ownership of tropical livestock unit (TLU) has positive and significant influence to adoption of wheat-chickpea double cropping. Besides, training on double cropping, access to improved seeds, access to BBM, access to fertilizer and access to market have significant and positive influence on adoption of wheat-chickpea double cropping in Becho woreda.

These factors are not the same with different farmers living in different agro-ecologies and different socio-cultural environments with different farming resources.

Among the above stated factors, training exposure, access to improved seeds and status of being model farmer (farmer type) have more influence on the decision of adoption of wheat-chickpea double cropping positively and significantly at 1% significant level. Whereas, involvement in non-farm income activities strongly and negatively affect adoption of wheat-chickpea double cropping at 1% significant level. On the other hand, variables like sex of household head, access to BBM and ownership of tropical livestock unit (TLU) influence farmers' decision to adopt wheat-chickpea double cropping positively and significantly at 5 % significance level. But, access to fertilizer, influences farmers' decision to adopt wheat-chickpea double cropping positively and significantly at 10 % significance level.

On the other hand, variables like age, family size, education, labor, owned land, bio-fertilizer (inoculant),access to credit, access to market and frequency of extension contact did not have significant influence on adoption of wheat-chickpea double cropping in the study area.

Besides, the study evaluated the impact of adoption of wheat-chickpea double cropping on yield and on farm income. The impact of adoption of wheat-chickpea double cropping on yield and farm income of smallholders' analyzed based on sample of matched treated and control groups. A propensity score matching (psmatch2) approach was used to compare adopter households with non-adopters in terms of yield which is measured in quintal per hectare (Q/ha) and farm income which is measured in Ethiopian birr. From the propensity score matching method, the estimated ATT found that adoption of wheat-chickpea double cropping had positive impact on treated farmers in terms of yield as well as farm income. Robustness of psmatch2 result was also checked by using different matching methods; such as: nearest neighbor matching, kernel matching method and stratification matching methods. In all the matching methods, average treatment effect (ATT) both on yield and farm income was found positive and strongly significant.

The treated sample households were found to have more yield difference Q/ha and income per year than the controlled sample households. The adoption decision of households for wheat-chickpea double cropping has generated about 18,564 birr difference in income per year from sale of both double cropped wheat and chickpea as ATT compared to the control and 6.96 q/ha difference in wheat yield advantage as ATT compared to the control group at statistically significant level; where t=3.46 and 5.34 for yield and farm income, respectively.

Therefore, the adoption of wheat-chickpea double cropping was found to have a positive impact on the adopters yield and farm income. Hence, encouraging farmers towards adoption of wheat-chickpea double cropping is necessary by properly addressing identified determinant factors.

5.2. Recommendations

On the basis of results of the study, (descriptive statistics and the econometrics models), recommendations are suggested for future research, policy and development intervention activities to promote adoption of wheat- chickpea double cropping so as to improve small holder farmers' productivity, income and livelihood from farm activities. Therefore, the following recommendations were generalized based on results of this study:

I. Improved seed is a limiting factor of adoption of wheat-chickpea double cropping. Farmers with better access to improved seeds are more likely to adopt the technology. Thus, adoption becomes more difficult in situations where shortage of improved seeds of wheat and chickpea exists. For better adoption of the technology, appropriate interventions in the area aimed to improve accessibility of the improved seeds status and increasing productivity of the small holders.

II. Training on double cropping of wheat-chickpea was found to positively and significantly influence adoption. Hence, concerned bodies should provide adequate and effective training on the subject to help the small holders acquire better skill and knowledge in properly implementing the technology, so as to benefit from it and improve their productivity and livelihood.

III. Livestock possession (TLU) is also an important determinant of adoption of wheat-chickpea double cropping in Becho area. Enhancing the livestock assets of the households is of vital importance. It provides manures for their farm, also helps as a means of transportation to take their farm produce to the market and to take farm inputs to their farm from market. It also provides financial support for the farmers during cash shortages times. Therefore, it is recommended that smallholder farmers need to be provided technical support especially medication and modern ways of feed and livestock management services so as to help the farmers improve their livestock asset and contribute to better adoption of double cropping.

IV. Farmer type is the other limiting factor to adoption of wheat-chickpea double cropping in the study area. Model farmers are much better to accept new technologies and adopt. To this effect, agricultural extension workers need to focus on different strategies to have more of model farmers in the system than focusing only on the existing ones for years and instead of specially supporting only those existing ones for years.

V. Access to Broad Bed Maker/ BBM/ Broad bed maker is a limiting factor of adoption of wheat-chickpea double cropping. As 85% of Becho woreda is covered by Vertisol, proper intervention should be made by concerned bodies in helping the local farmers access to the preferred Aybar BBM or any better than the heavy version. By doing so, farmers could be well helped to replace the local low performing ‘Shaga’ and help them adopt the double cropping and contribute to their food security and livelihood improvement; through improved means of production.

VI. Access to fertilizer is found to be a limiting factor. Interventions with regards to good road access to cooperatives and agricultural offices from where the farmer could purchase would be good to tackle the accessibility problem by one side. On the other hand, having Ethiopia as an agrarian country striving to achieve food security, proper policy need to be formulated and put to use in line with subsidizing fertilizer costs. Farmers need to apply recommended amount, but due to the increasing fertilizer price over years, farmers are being discouraged from using full package. Basically, for the double cropping purpose; blended fertilizer (NPSB) and UREA were the focus of interest in the context of Becho. Due to chickpeas contribution in fixing atmospheric nitrogen, adopters purchase 50-60 kg/ha UREA less of the recommended amount for wheat.

Generally, the findings suggest that, in such time of food insecurity, rural land fragmentation problem, and soil fertility problem in the country, Ministry of agriculture (MoA) and key stakeholders need to focus on promoting double cropping practice as one feasible measure in Vertisol dominant areas so as to exhaust the opportunity from the cropping system. It is suggested that, promotion of the technology need to be through the provision of better access to improved seeds, better access to efficient BBM (AYBAR or better), proper training on double cropping, efficient support in livestock productivity, encouraging participation in non-farm activities, improving timely accessibility of recommended fertilizers for the farmers in the target Becho woreda.

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APPENDIX:

I. Conversion factor

Conversion factors used to calculate Tropical Livestock Units (TLU)

No	**Animals**	Tropical Livestock Unit (**TLU)-equivalent**
1	Calf	0.20
2	Heifer and Bull	0.75
3	Cows and Oxen	1
4	Camel	1.25
5	Horse	1.10
6	Donkey	0.70
7	Sheep and goat	0.13
8	Chicken/ Paultry	0.013

Source: Strock *et al*. (1991)

II. Questionnaire

Questionnaire for farm House holds

Dear participants,

I am a graduate student of Addis Ababa University, College of Development Studies, and center for rural Development. Currently, I'm conducting a study on the title "Adoption of Wheat-Chickpea double cropping and its impact on yield and farm Income; in Becho woreda; South West Shoa Zone, Oromia region, Ethiopia.*"* Purpose of the research is to assess the adoption status along with its determinants and to measure impacts of adopting the technology of Wheat - Chickpea double cropping. Having done with that, the purpose is to come up with information regarding status of adoption of double cropping and its contribution to the welfare of HHs who adopted the technology in terms of yield per hectare and farm income in the target woreda.

Remark: Your sincere and genuine cooperation in answering each question is highly important for the success of the study. The information you provide will be treated confidentially and will only be used for academic purposes. Please give the right answers to the following questions to the best of your knowledge

Thank you in advance

Instructions to Enumerators

1. Make sure the house hold head or representative member of the household whose age is 18 years or more is the appropriate respondent of this questionnaire.
2. Briefly introduce yourself to the farmer before starting any question (Your name and organization)
3. Greet them in local ways and clarify objective of the study.
4. Fill the interview schedule according to the farmers reply (do not put your own feeling).
5. Ask each question clearly and politely till the farmer gets your points well; all through.
6. Please do not use technical terms and do not forget local units.
7. Check that all questions and responses are correctly filled accordingly

1. **General information**

Instruction: For the questions below, provide appropriate answer by using a tick mark or by circling or by stating where ever necessary to indicate your appropriate response.

1.1. Questionnaire no. (code): _______
1.2. Date of interview (DD/MM/YYY):__________
1.3. Woreda_________ Kebele) ______________
1.4. Name of enumerator ________________________________
1.5. Name of respondent (HH head) or representative of the HH ___________

2. Household characteristics

2.1. Sex of household head: ______________1. Male 0=.Female

2.2. Age of respondent (household head) in years : _________________

2.3. Adoption status:______________1= adopter 0= Non adopter

2.4. Marital status of the household head 1. Married 2. Single 3. Divorced 4. Widowed

2.5. Religion 1= Christian 2= Muslim 3= other

2.6. What is your education level? (Can you read and write?) _____1= yes, 2=No.

2.7. If yes, your type of education: (1) formal (0) non formal and years attended______.

2.8. Years lived in the area?______________(in years).

2.9. What type of farmer are you?_________1=model (A & B) , 0= non model (C)

3. Demographic Characteristics

3.1. Number of family members by sex and age Composition

S.No	Name of HH members (start with respondent)	Age	R/ ship to the HH head	Sex	
				M	F
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
		Total			

3.2. How many of your family members are helping on farm activities: _____

4. Adoption related issues - wheat-chickpea double cropping.

4.1. What type of soil dominates your farm land?________

1=Vertisols   2= Nitisols   3= Luvisols

4.2. What is the length of time since you first heard about double cropping of wheat and chickpea? _______________Years, since _____________(in E.C.)

4.3. If adopter, when did you decide to adopt the wheat –chickpea double cropping? since_________________ (in E.C.)

4.4. If adopter, farming experience of the household head with production of wheat-chickpea double cropping? __________years.

4.5. If adopter, before that, what were you cultivating?_______________________

4.6. How long is your general farming experience as a whole? ___________in years.

4.7. From whom/where did you first hear about double cropping technology of wheat and chickpea? ________ 1= Development agent   2=Research Center

3=project such as CASCAPE   4=Neighbors   5=Farmers' organizations

6. Others (specify) ____

4.8. Do you use bio fertilizers (inoculants?) for chickpea's N fixation?_____

1= Yes   0=No

4.9. If yes, how long have you been using inoculant bio-fertilizer; to support chickpea fix atmospheric nitrogen? _______________Years (in E.C.)

4.10. What is your dominant farming experience in allocating farm land? ______

1= double cropping ; 0= mono cropping.

4.11. If adopter, what are significances of adopting wheat –chickpea double cropping for you (more than one answer is possible, if any?)
1= improves yield
2= improves soil fertility
3= reduces fertilizer expense
4= contributes to food security (two harvest in one season)
5= all 6= other, specify____

4.12. List the major problems in wheat–chickpea double cropping? (More than one answer is possible, if any.) ________
1= Lack of improved seed, 2= Lack of inoculant,
3=pests and disease, 4=Lack of credit
5=lack of rainfall (drought) 6=Lack of market,
7= Lack of labor 8 =lack of improved seeds and inoculants
9=Lack of improved seeds , pest and diseases, 10=Lack of improved seeds and lack of rainfall/ drought 11= Others (specify)
____

5. **Labor availability**

5.1. Do you face labor shortage for farming activities?_______1. Yes 0. No

5.2. If yes, for which operation/s? (multiple answer is possible) ________
1. Plowing 2. Planting 3. Weeding 4. Harvesting 5.Threshing 6.Plowing and harvesting 7. Planting and harvesting 8. Plowing and planting 9. All

5.3. How do you overcome labor shortage?_____________
1. Family labor 2. Debo /Jigi/ 3. Hired labor
4. Family labor and hired labor 5= family labor and Debo /Jigi/
6. Other, specify_____________________________________

5.4. If you hire labor, how many laborers do you hire per year? _____________

6. **Socio economics Characteristics**

6.1. Landholding status (ha):________________1=owned 2=rented,

6.2. Did you rent-in land during the last cropping season? 1. Yes 0. No

6.3. Rented in landholding in hectare: _______Price per hectare/year _________ETB.

6.4. What is the percentage share of the annual production (q/ha)___________?

6.5. Owned landholding in hectare (owned)________

6.6. Total land used to cultivate wheat–chickpea double cropping in hectare; 2010/11_____ha, 2009/10_____ha, 2008/9_______ha.

6.7. Did you rent out your land during 2009/10 cropping season? 1. Yes 0. No

6.8. If yes, area of land rented out during the season in hectare_______.

6.9. Price per hectare/year ____ETB.

6.10. Does adoption of wheat-chickpea double cropping meaningfully increase productivity?_________ 1 = yes , 0= No

6.11. How many months of the year you faced lack of food for your family before adoption of double cropping? 1. No month 2. One Month 3. Two months 4. Three months 5. Four months 6. Five months 7. Six month and more_______ (state the year, if any)

6.12. Did you face lack of food after adoption? If yes, for how many months?

1. One month 2. Two months 3. Three months 4. Four months 5. Five months 6. Six months and more _________ (state the year, if any)

6.13. Your current farming status? ______________ 1= surplus, so that you have enough food for your family and enough to sell. 2 =Subsistence 3= subsistence

6.14. Non-farm activities

6.14.1. Do you involve in non- farm activities? 1. Yes 2. No

6.14.2. If Yes, type of non-farm activities and their contribution for monthly income (consider the table below)

	Activities	Days per week spent	Hours spent per day	Average monthly income
1	Petty(minor) trade			
2	Salary employment			
3	Handcraft			
5	Grain and livestock trade			
6	Charcoal making			
7	Casual labor			
8	Remittance			
9	Others			

7. Production of wheat –chickpea double cropping trend based on inputs used in 3years

7.1. Consider table below to answer production trend in the past three years production

Production, based on farm size and inputs used:	Year in E.C		
	2008/09	2009/10	2010/11
Annual total production (Q/ha): **Double cropping (Adopter)**			
-Improved wheat			
-Improved chickpea:			
-Kabuli (white)			
-Desi (brown)			
Annual total production(Q/ha): **mono cropping(non-adopter)**			
-Improved wheat			
Farm size used in (ha) for double cropping (planting wheat)			
Farm size used in (ha) for double cropping (planting chick pea			
DAP or **Blended** fertilizer used in kg/ha for wheat (underline; which)			
Fertilizer used for chickpea in Kg/ha			

UREA used in kg/ha for wheat Kg/ha			
UREA used in kg/ha for chickpea Kg/ha			
Inoculant (Bio fertilizer) used (in grams per hectare			
Seed used in kg/ha for wheat			
Seed used in kg/ha for chickpea			
Herbicide used in (L) for wheat			
Herbicide used in (L) for chickpea			
Pesticide(L) for wheat			
Pesticide(L) for chickpea			

7.2. Which types of wheat and chickpea varieties are more compatible for double cropping? Wheat: 1st___________,2nd __________,3rd ___________

why____

Chickpea: 1st___________,2nd ___________3rd ____________________

Why?____

8. Farm income 2009/10 E.C,

8.1. What is the source of income for your household in order?

1= Crop cultivation 2= Animal husbandry 3= animal bi products

4= non-farm income 5= crop cultivation and animal bi-product

6= crop cultivation and animal husbandry

7= other (please specify) ____

8.2. Household's farm income from sale of crops in 2017/2018 or 2009/10

No	Commodity	Annual harvest(qt)	Consumed (qt)	Amount sold(qt)	Price (Birr/qt)	Income earned(Birr)
Double cropping (for adopters)						
1	Improved wheat					
2	Improved chickpea:					
	-Kabuli					
	-Desi					
Mono cropping (for non-adopters)						
1	Improved Wheat					
2	Improved Chickpea:					
	-Kabuli					
	-Desi					

8.3. Total annual income from farm activities in 2009/10 E.C., in birr______________________.

8.4. Household's farm income from sale of Livestock in TLU; in 2017/2018 or 2009/10E.C

Category	Number	Value (Birr)	Animals sold lastyear (no.)	Bi-productsof animals soldlast year in Birr	Total income in Birr
Cows					
Oxen					
Heifers					
Bulls					
Calves					
Sheep					
Goats					
Donkeys					
Horses					
Mules					
Poultry					

9. Institutional characteristics

9.1. **Training:**

9.1.1. Have you been given formal training on double cropping of wheat and chickpea, given the potential in Becho woreda? ______0= Not trained, 1= yes, trained.

9.1.2. If 'Yes', was the training effective and made you skillful to practice the double cropping much better? ____________1= No, it was not totally effective, 2= it was moderately effective 3= it was very effective and I'm made skillful in that regard.

9.1.3. What is your perception regarding wheat –chickpea double cropping?

1=I know it; it increases yield and improves soil fertility

2= It is not much clear 3= I don't know it so far

4=Please add if you have any more__________________________

9.2. **Access to credit:**

9.2.1. Do you have access to credit?___________ 1=Yes 0= No

9.2.2. If yes, source of credit?_____________1=Cooperatives 2= Oromia credit and saving institute(OCSI) 3=Bank 4=Relatives / friends / neighbors 5=Eder /'Afoosha'/ 6= Ekub 7=Others_______

9.2.3. If no, why don't you have access to credit?___________1=No institution that provides credit 2= High interest rate 3= Lengthy procedure 4.I have enough and no need of taking credit

9.2.4. Purpose of credit?__________ 1= To purchase fertilizer 2= To purchase seed 3=To purchase oxen 4=To purchase sheep 5=For fattening 6=To start- non-farm business 7= Other, specify_______________

9.3. **Access to input and output market**

9.3.1. Distance to the nearest market centers (in km______) minutes of walking________________ by car ___________minutes.

9.3.2. Where do you sell your farm output? __________ 1= Cooperative
2= Nearest local market 3= District market 4=Zonal market
5= Regional Market 6= Others, specify_____________

9.3.3. Do you have access to improved seeds of wheat ?_________ 1=Yes 0= No

9.3.4. Do you have access to improved seeds of chickpea?_________ 1=Yes 0= No

9.3.5. If you have access, where do you buy improved seeds? 1=Cooperatives 2= Nearest local market 3= woreda (TuluBolo) market 4= Zonal market 5= Regional Market 6=Others, specify_____________

9.3.6. Distance to the nearest source of seed (km) minutes of walking____________

9.3.7. Do you have access to farm chemicals?_________________ 1=Yes 0= No

9.3.8. If Yes, where do you buy farm chemicals? 1=Cooperatives 2= Nearest local market 3= woreda (TuluBolo) market 4= Zonal market 5= Regional Market 6=Others, specify_____________

9.3.9. If yes, where do you buy farm chemicals? ______________________

9.3.10. Distance to the nearest farm chemicals supply center (in km_________) minutes of walking____________

9.3.11. Do you have access to broad bed maker (BBM) ? 1=Yes 0= No

9.3.12. Do you use broad bed maker (BBM) to drain excess water? 1- yes, I do, 2= No I don't use it, 3= I use other means 4=other ,specify______________

9.3.13. If you don't use broad bed maker (BBM), please specify your reason:
1. The available one is very heavy for oxen. 2. Modified Aybar BBM is not accessible 3.We have better tool 4. Lack of money 5. Lack of training
6 The available one is very heavy for oxen and Aybar broad bed maker (BBM) is not accessible.
7.Lack of appropriate information on broad bed maker (BBM)

9.3.14. If you use, where do you get BBM? 1=Cooperatives 2= Nearest local market 3= District market 4= Zonal market 5= Regional Market 6=Others, specify_____________

9.3.15. Distance to the nearest broad bed maker (BBM) supply center (in km_________) minutes of walking____________

9.3.16. Do you have access to fertilizer? 1=Yes 0= No

9.3.17. Distance to the nearest fertilizer supply center (in km_________) minutes of walking____________

9.3.18. Where do you buy fertilizer? _____________________1=Cooperatives 2= Nearest local market 3= District market 4= Zonal market 5= Regional Market 6=Others, specify_____________

9.3.19. What types of fertilizers do you buy to cultivate wheat ______________chickpea ___________under double cropping;

9.3.20. What kind of fertilizers you don't purchase due to chickpea's contribution to soil fertility and show how much you saved in (kg/ha); ____________________

9.3.21. If adopter, when do you apply large amount of nitrogen fertilizer? 1= during mono cropping of wheat in kg/ha__________2= During double cropping of wheat and chickpea in Kg. /ha ______________

9.3.22. If adopter, do you think double cropping practice has improved fertility of your farm land (soil) ? 1= Yes 0= No

9.3.23. If yes, how____

9.3.24. If adopter, how was fertility status of your farm land before adopting the double cropping?

1. Degraded than it is now 2. Same as now

9.3.25. Do you have shortage of inoculant for chickpea production?

1=Yes 2= No 3=medium

9.3.26. Where do you buy bio inoculant?_______________________

9.3.27. Distance to the nearest bio inoculant supply center (in km_________) minutes of walking____________

9.3.28. Do you have access to market? 1=Yes 0= No

9.4. **Extension services**

9.4.1. Distance from your house to agricultural development station (kebele)? in Km _______minutes of walking______ by car _______in minutes

9.4.2. **SMS visit:**

How often the extension agents from woreda visit and provide you technical support?

1= None in a week 2. Days in a week

3= Days in two weeks 4. In three weeks or a month

9.4.3. If so, how did the SMS help you? __________1.Practical assistance at farm 2.Demonistartion 3.Training at FTC 4.other (please specify) ____

Any suggestion or comment about wheat –chickpea double cropping activities
____
____

III. Checklist for Focused Group Discussion /FGD/

1.1. What is the trend of wheat-chickpea double cropping in Becho woreda?4

1.2. When and from who did you first hear about double cropping of wheat and chickpea?

1.3. When did you decide to adopt the wheat –chickpea double cropping? *(Only adopters respond)*
1.4. Is double cropping of wheat and chickpea better off than mono cropping? If so what are its significances?
1.5. How much land are you allocating to double cropping of wheat and chickpea, in proportion to your total land?
1.6. What other crops do you grow and how much land do you allocate to mono crops stated?
1.7. What is the length of time since you first heard and used inoculant bio-fertilizer; to support chickpea fix atmospheric nitrogen? Explain it along with amount of nitrogen fertilizer you're using since double cropping and before.
1.8. Do you have access to farm inputs such as: improved seeds, fertilizers, inoculants, chemicals, broad bed maker (BBM), credit and the likes?
1.9. Do you get extension service from the SMS and DAs? If so how often do they visit you and what kind of support do you get? (Explain SMS's and DAs separately)
1.10. Have you been trained about double cropping technology? If so, how often, which institution delivered, for how many days and when was it?
1.11. Do you have labor shortage? If so how do you manage?
1.12. What are your sources of income? Are you engaged in any non-farm activities? Explain.
1.13. What support do you think the farming community here need from concerned bodies so that adoption of wheat –chickpea will be accelerated given the potential of the woreda.
1.14. What are the major problems of wheat-chickpea double cropping here in Becho

IV. Estimated result of probit model likelihood of adoption of wheat-chickpea double cropping and respective marginal effect (dy/dx).

```
Iteration 5:   log pseudolikelihood = -23.895936

Probit regression                               Number of obs     =        203
                                                Wald chi2(17)     =      80.49
                                                Prob > chi2       =     0.0000
Log pseudolikelihood = -23.895936               Pseudo R2         =     0.8260
```

AdopStats	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Sex	1.778759	.8507963	2.09	0.037	.1112294	3.446289
Age	-.0121786	.0135033	-0.90	0.367	-.0386447	.0142875
Educ	.2259717	.3757861	0.60	0.548	-.5105554	.9624988
FarmrType	1.374255	.4870288	2.82	0.005	.4196964	2.328814
totl_family_size	-.0958497	.0762764	-1.26	0.209	-.2453487	.0536493
Do_U_face_Labr_shortge	.1424668	.3402416	0.42	0.675	-.5243945	.8093281
OwnedLandinHectr	-.0627506	.1952283	-0.32	0.748	-.4453911	.3198899
InvolveOffFarm	-.9611891	.2666959	-3.60	0.000	-1.483903	-.4384747
ToT_TLU	.106206	.0417156	2.55	0.011	.0244449	.1879671
TrainingonDC	2.273615	.5962665	3.81	0.000	1.104954	3.442276
AccesstoImprovedSeeds	1.92198	.3414603	5.63	0.000	1.25273	2.59123
AccessBBM	1.001786	.4231156	2.37	0.018	.1724951	1.831078
AccessFertilizer	1.031105	.5850208	1.76	0.078	-.1155146	2.177725
ShortageofInoculant	-.0004632	.2177343	-0.00	0.998	-.4272146	.4262883
Access_to_market	.5503139	.3911537	1.41	0.159	-.2163332	1.316961
AccessToCredit	.0097332	.1773354	0.05	0.956	-.3378379	.3573042
FrequencyExtensioncontct_SMS	.1371003	.2012415	0.68	0.496	-.2573259	.5315264
_cons	-6.176437	1.790758	-3.45	0.001	-9.686258	-2.666616

```
. margins, dydx(*)

Average marginal effects                        Number of obs     =        203
Model VCE    : Robust

Expression   : Pr(AdopStats), predict()
dy/dx w.r.t. : Sex Age Educ FarmrType totl_family_size Do_U_face_Labr_shortge OwnedLandinHectr
               InvolveOffFarm ToT_TLU TrainingonDC AccesstoImprovedSeeds AccessBBM AccessFertilizer
               ShortageofInoculant Access_to_market AccessToCredit FrequencyExtensioncontct_SMS
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
Sex	.1231018	.0601068	2.05	0.041	.0052947	.240909
Age	-.0008428	.0008967	-0.94	0.347	-.0026004	.0009147
Educ	.0156387	.0244672	0.64	0.523	-.032316	.0635935
FarmrType	.0951075	.0304832	3.12	0.002	.0353614	.1548536
totl_family_size	-.0066334	.0051165	-1.30	0.195	-.0166616	.0033947
Do_U_face_Labr_shortge	.0098596	.0244265	0.40	0.686	-.0380155	.0577347
OwnedLandinHectr	-.0043428	.0130516	-0.33	0.739	-.0299235	.021238
InvolveOffFarm	-.0665206	.02759	-2.41	0.016	-.120596	-.0124452
ToT_TLU	.0073502	.0035948	2.04	0.041	.0003044	.0143959
TrainingonDC	.1573491	.0228289	6.89	0.000	.1126053	.2020929
AccesstoImprovedSeeds	.1330136	.028764	4.62	0.000	.0766373	.18939
AccessBBM	.0693302	.0213718	3.24	0.001	.0274422	.1112182
AccessFertilizer	.0713592	.0346525	2.06	0.039	.0034416	.1392768
ShortageofInoculant	-.0000321	.0150674	-0.00	0.998	-.0295636	.0294995
Access_to_market	.0380853	.0218264	1.74	0.081	-.0046936	.0808643
AccessToCredit	.0006736	.012339	0.05	0.956	-.0235104	.0248576
FrequencyExtensioncontct_SMS	.0094882	.014099	0.67	0.501	-.0181452	.0371217

.

V. Multicolleniarity Test (Contingency coefficient test)

```
. pwcorr Sex Age totl_family_size Do_U_face_Labr_shortge OwnedLandinHectr InvolveOffFarm ToT_TLU Trainingo
> nDC AccesstoImprovedSeeds AccessBBM AccessFertilizer ShortageofInoculant Access_to_market FrequencyExten
> sioncontct_SMS FarmrType
```

	Sex	Age	totl_f~e	Do_U_f~e	OwnedL~r	Involv~m	ToT_TLU
Sex	1.0000						
Age	-0.0433	1.0000					
totl_famil~e	0.1387	0.2017	1.0000				
Do_U_face_~e	-0.0173	0.1119	-0.1501	1.0000			
OwnedLandi~r	0.1498	0.1985	0.2604	0.1159	1.0000		
InvolveOff~m	-0.0090	-0.0541	-0.0655	-0.1350	-0.2535	1.0000	
ToT_TLU	0.0351	0.1954	0.2478	0.1445	-0.0518	0.1415	1.0000
TrainingonDC	-0.0295	0.1379	0.3313	0.1507	0.2756	-0.0987	0.2238
AccesstoIm~s	-0.0314	0.0978	0.0909	0.2194	0.1909	-0.0231	0.2097
AccessBBM	-0.0175	0.1368	0.1818	0.2114	0.2302	-0.1053	0.2420
AccessFert~r	-0.3169	0.1677	-0.1537	-0.0052	-0.0030	0.0189	-0.0728
Shortageof~t	-0.0255	-0.0665	-0.0696	-0.0423	-0.1804	0.1810	0.1408
Access_to_~t	-0.0215	0.0072	0.0719	0.0860	0.1909	-0.1391	0.0928
FrequencyE~S	-0.0756	0.1137	-0.2088	-0.0522	-0.1251	0.0234	0.0169
FarmrType	0.0172	0.0630	0.1830	0.1845	0.2341	0.0706	0.3421

	Traini~C	Acces~ds	Access~M	Access~r	Shorta~t	Acces~et	Freque~S
TrainingonDC	1.0000						
AccesstoIm~s	0.5343	1.0000					
AccessBBM	0.5900	0.6715	1.0000				
AccessFert~r	-0.0495	-0.0264	-0.0363	1.0000			
Shortageof~t	-0.1462	-0.1913	-0.1377	-0.0370	1.0000		
Access_to_~t	0.3386	0.3630	0.4048	-0.0535	-0.1406	1.0000	
FrequencyE~S	-0.1935	-0.0948	-0.2151	0.1067	0.0062	-0.2131	1.0000
FarmrType	0.3837	0.3989	0.4399	-0.0758	-0.0688	0.3214	-0.1928

	FarmrT~e
FarmrType	1.0000

Note: the common support option has been selected. The region of common support is [.0009342, 1]

VI. Pscore estimation

The balancing property is satisfied

This table shows the inferior bound, the number of treated
and the number of controls for each block

Inferior of block of pscore	adoption status non adopt	adopter	Total
.0015934	90	2	92
.2	7	2	9
.4	4	6	10
.6	1	8	9
.8	5	65	70
Total	107	83	190

Note: the common support option has been selected

VII. Balancing measures for matching quality

```
. pstest, graph both
```

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|	V(T)/ V(C)
Sex	U	.93976	.925	5.9		0.41	0.685	.
	M	.93976	.93976	0.0	100.0	0.00	1.000	.
TrainingonDC	U	.95181	.21667	222.9		14.85	0.000	.
	M	.95181	.95181	0.0	100.0	0.00	1.000	.
Age	U	44.518	42.242	22.8		1.57	0.117	0.74
	M	44.518	44.072	4.5	80.4	0.37	0.715	2.21*
Access_to_market	U	.81928	.33333	112.4		7.73	0.000	.
	M	.81928	.84337	-5.6	95.0	-0.41	0.681	.
AccessBBM	U	.91566	.15833	232.3		15.89	0.000	.
	M	.91566	.90361	3.7	98.4	0.27	0.788	.

.

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.675	185.38	0.000	119.2	112.4	318.9*	0.49*	0
Matched	0.002	0.38	0.996	2.7	3.7	9.5	1.08	100

VIII. ATT_Yield (Q/ha) _psmatch2

.

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Yield_Wheat_p~10	Unmatched	23.1144578	16.525	6.58945783	.778609362	8.46
	ATT	21.2142857	14.25	6.96428571	2.01195895	3.46

IX. ATT_ farm income *(Birr/annum) _psmatch2*

.

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
ToT_Income_Wht~p	Unmatched	26354.0361	5087.5	21266.5361	1513.3288	14.05
	ATT	22692.8571	4128.57143	18564.2857	3475.91229	5.34

X. Results of matching algorithms_*(Robustness check)*

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
83	51	9.273	2.198	4.218

ATT estimation with Nearest Neighbor Matching method
(random draw version)
Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
83	51	22064.768	2304.135	9.576

ATT estimation with the Kernel Matching method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
83	72	9.321	1.180	7.903

ATT estimation with the Kernel Matching method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
83	72	22715.459	1961.793	11.579

ATT estimation with the Stratification method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
83	72	9.229	1.452	6.356

ATT estimation with the Stratification method
Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
83	72	22681.695	2030.761	11.169

XI. Sensitivity analysis_1: Yield_ wheat production

```
. do "C:\Users\user\AppData\Local\Temp\STD00000000.tmp"

. gen rho = Yield_Wheat_prdcn_2009_10 - _Yield_Wheat_prdcn_2009_10 if _treated==1 & _support==1


. rbounds rho, gamma(1(0.05)2)
```

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	3.3e-15	3.3e-15	12	12	10.5	13.5
1.05	1.5e-14	6.7e-16	12	12	10	14
1.1	5.7e-14	1.1e-16	12	12	10	14
1.15	2.0e-13	0	11.5	12.5	10	14
1.2	6.1e-13	0	11.5	12.5	10	14
1.25	1.7e-12	0	11.25	12.5	10	14
1.3	4.6e-12	0	11	13	9.75	14
1.35	1.1e-11	0	11	13	9.5	14.5
1.4	2.6e-11	0	11	13	9.5	14.5
1.45	5.6e-11	0	11	13	9.25	15
1.5	1.2e-10	0	11	13	9	15
1.55	2.3e-10	0	10.5	13	9	15
1.6	4.3e-10	0	10.5	13	9	15
1.65	7.8e-10	0	10.5	13.5	9	15
1.7	1.4e-09	0	10.5	13.5	8.5	15
1.75	2.3e-09	0	10	14	8.5	15
1.8	3.9e-09	0	10	14	8.5	15
1.85	6.2e-09	0	10	14	8.25	15.5
1.9	9.8e-09	0	10	14	8	15.5
1.95	1.5e-08	0	10	14	8	15.5
2	2.3e-08	0	10	14	8	15.5

```
* gamma  - log odds of differential assignment due to unobserved factors
  sig+   - upper bound significance level
  sig-   - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+    - upper bound confidence interval (a=  .95)
  CI-    - lower bound confidence interval (a=  .95)
```

XII. Sensitivity analysis 2: Farm income wheat ad chickpea

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	1.2e-15	1.2e-15	23350	23350	19700	27550
1.05	5.7e-15	2.2e-16	22850	23700	19350	27800
1.1	2.3e-14	0	22500	24150	19000	28200
1.15	7.9e-14	0	22200	24580	18650	28500
1.2	2.5e-13	0	21950	24950	18450	28850
1.25	7.3e-13	0	21650	25300	18200	29100
1.3	2.0e-12	0	21300	25700	17800	29400
1.35	4.8e-12	0	21050	25900	17600	29700
1.4	1.1e-11	0	20800	26250	17300	30000
1.45	2.5e-11	0	20600	26500	17050	30200
1.5	5.2e-11	0	20375	26800	16750	30500
1.55	1.0e-10	0	20200	27000	16450	30800
1.6	2.0e-10	0	19950	27350	16300	31000
1.65	3.6e-10	0	19750	27550	16000	31300
1.7	6.4e-10	0	19600	27700	15850	31500
1.75	1.1e-09	0	19350	27800	15600	31700
1.8	1.8e-09	0	19150	28050	15350	32000
1.85	3.0e-09	0	18975	28200	15250	32200
1.9	4.7e-09	0	18700	28400	15050	32450
1.95	7.3e-09	0	18600	28600	14850	32700
2	1.1e-08	0	18500	28750	14700	33000

```
* gamma  - log odds of differential assignment due to unobserved factors
  sig+   - upper bound significance level
  sig-   - lower bound significance level
  t-hat+ - upper bound Hodges-Lehmann point estimate
  t-hat- - lower bound Hodges-Lehmann point estimate
  CI+    - upper bound confidence interval (a=  .95)
  CI-    - lower bound confidence interval (a=  .95)
```

===