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The impact of row planting of teff crop on rural Household income: A case of Tahtay Maychew wereda, Tigrai, Ethiopia

By Yonas Berhe

A Thesis Submitted in Partial Fulfillment of the Requirements for the Masters of Science degree in Economics

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DECLARATION

This is to certify that this Thesis entitled "The impact of row planting of teff crop on rural Household income (Tahtay Maychew wereda, Tigrai, Ethiopia)" Submitted in partial fulfillment of the requirement for the award of degree of MSc in Economics (Development Policy Analysis) to the department Economics, Mekelle University, done by Mr. Yonas Berhe I.D No CBE/PE:098/05 is an authentic work carried out by him under my guidance. The matter embodied in this project work has not been submitted earlier for award of any degree or diploma to the best of my knowledge and belief.

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ABSTRACT

Adoption of yield increasing technologies is seen as a key driver to increase agricultural production in Ethiopia. There is, however, a lack of empirical evidence on the impact of programs aiming to scale-up the adoption of improved technologies from research settings to the farm level. To fill this gap, this paper assesses the impact of the row planting technology specifically teff crop on farm household income in Tahtay Maychew wereda Tigrai regional state. Both descriptive and econometric data analysis techniques were applied. The analysis was based on primary household level cross sectional data collected from 300 randomly selected rural households of which 120 of them were participants and the remaining 180 were nonparticipants and secondary data were employed. We applied the propensity Score Matching (PSM) and Heckman two stage selection model. The results of a propensity score matching show that the adoption of row planting had increased the teff crop income by about 1062.667 Birr per year for NNM, which is significant at 5% probability level, 1077.854 birr per year for SM which is significant at 1% probability level, 1004.172 birr per year for KM which is significant at 1% probability level and 1959.602 birr per year for RM which is significant at 1% probability level, on average compared to the non-adopters. In the first stage of the Heckman two-step procedure six variables were found to determine participation in row planting technology. After the selectivity bias is controlled by the model in the second stage the inverse Mills ratio (LAMBDA) variables and other three variables were found to have significantly determined household teff crop income.

Key words: Row planting, teff, propensity score matching, Heckman two stage

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ACRONYM

ATT	Average Treatment On Treated
BoPF	Bureau of plan and finance
CSA	Central Statically Agency
FTC	farmers training center
GDP	Gross Domestic Product
KM	Kernel matching
MoFED	Ministry of Finance and Economic Development
NNM	Nearest Neighbor matching
RM	Radius Matching
RP	Row planting
SM	Stratification matching
PSM	Propensity Score Matching
TLU	Tropical Livestock Unit
VIF	variance inflation factors
WeARD	wereda office of Agriculture and Rural Development

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1. CHAPTER ONE: INTRODUCTION

1.1. Background of the study

From time of the olden days, agriculture remains the backbone of Ethiopia's economy and still expected to play a dominant role in the years to come. Agriculture employs about 83% of the total population and 90% of the total export earnings, 43% of Gross Domestic Product (GDP) and provides about 70% of the county's raw material requirement for large and medium scale industries (MOFED, 2013). Hence, the performance of the agricultural sector largely determines the performance of the entire economy of the country.

Nevertheless, it is mainly characterized by rain fed, subsistence oriented, smallholder production system and traditional farming practices. The other factors related to poor agricultural performance are reduced soil fertility, unreliable climatic conditions, poor infrastructure, environmental degradation, and land scarcity have resulted in low crop yields and income variability, on the one hand and high population growth rate on the other. Thus, agricultural production fails to keep pace with population growth rate in the last three decades. As a result, quite a significant proportion of population lives in poverty MoARD (2001).

Through institutional and policy reforms, Ethiopia has been achieving strong and promising economic growth in the past decade (MoFED, 2013). The witnessed economic growth is believed to be the result of the Poverty Reduction Strategy designed by the Ethiopian government with subsequent policy eras of Sustainable Development and Poverty Reduction Program (SDPRP) for year 2002/03-2004/05; Plan for Accelerated and Sustained Development to End Poverty (PASDEP) for year 2005/06-2009/10 and Growth and Transformation Plan (GTP) for 2010/11-2014/15. To date SDPRP and PASDEP have been formulated with major emphasis given to Agricultural Development-Led Industrialization (ADLI) since agriculture sector is the source of the country's livelihood (MoFED, 2013). Even if Ethiopia recorded highest performing economies in sub-Saharan Africa, 29% of the population still lives below the national poverty line (IFAD, 2009). In 2011, World Bank reported that 83% of Ethiopian population resides in the rural part of the country where poverty is significantly severe and livelihood strategy is dependent on small scale farming or livestock herding. With 1.8% annual rural population growth in Ethiopia (World Bank, 2011), promoting Sustainable Agriculture and

Rural Development (SARD) in order to satisfy the demands of the increasing population for food and other agricultural commodities is important.

Over the last three decades, the government of Ethiopia and a consortium of donors have undertaken a massive program of natural resource conservation to reduce environmental degradation, poverty, and increase agricultural productivity and food security. However, the adoption and adaptation rate of sustainable land management (SLM) practices is low. In some cases, giving up or reducing the use of technologies has been reported (Kassa 2003; Tadesse and Kassa, 2004). A number of factors may explain the low technology adoption rate in the face of significant efforts to promote SLM practices: poor extension service system, blanket promotion of technology to very diverse environments, top-down approach to technology promotion, late delivery of inputs, low return on investments, escalation of fertilizer prices, lack of access to seasonal credit, and production and consumption risks.

For instance, *teff* which is one of the staple food crop of Ethiopians, is believed to be originated, domesticated and diversified in the country. It is a hugely important crop to Ethiopia, both in terms of production and consumption. In a country of over 80 million people, *Teff* accounts for about 15% of all calories consumed in Ethiopia. Furthermore, approximately 6 million households grow teff and it is the dominant cereal crop in over 30 of the 83 high-potential agricultural *woredas* (MOA, 2011). In terms of production, *Teff* is the dominant cereal by area planted and second only to maize in production and consumption. However, yields are relatively low (around 1.2 tones/ha) and suffer from high loss rates (25-30% both before and after harvest). As a result of this it reduces the quantity of grain available to consumers by up to 50%. Furthermore, while wholesale prices for *Teff* are relatively high, making the crop attractive to some producers as a cash crop, production costs are also high, implying fertilizer prices and the labor intensive nature of the crop (ATA Ethiopia 2009). Despite the relative high cost structure, however, production has been increasing at approximately 11%per year (due to land expansion and increase in yield), with high latent demand resulting in price increases as well. According to BoARD , Row planting technology was introduced in 2010/2011 at farm level. The research is intended to investigate the impact of sowing in line on household income specifically *teff* crop in *Tahtay maychew wereda*.

1.2. Statement of the problem

In Ethiopia, small-scale subsistence farmers are dependent on low input, rain-fed mixed farming agriculture dominated with traditional technologies accounts for about 95% of the output (Pender et al., 2002). Agricultural production and productivity is very low and the growth in agricultural output has barely kept pace with human population growth.

In Ethiopia, *teff* is a highly valued crop and is primarily grown for its grain that is used for preparing *injera*, which is a staple and very popular food in the national diet of Ethiopians. It can also be used in many other food products such as *kitta* (unleavened bread), *anebaberro* (double layered *injera*), porridge and alcoholic beverage such as *tella* and *katikala* (Asrat and Frew, 2001). Seyfu (1993) suggested that *teff* is not suitable for bread making as it lacks the necessary amount and quality of protein complex called "*gluten*" that can be formed into dough with the rheological properties required for the production of leavened bread. According to the National Academy of Science (1996), *teff* contains no gluten thus American's with severe allergies to wheat gluten are among those buying *teff* these days.

However, the method of sowing which is practiced in Tigrai regional state as well as in other part of the country is hand broadcasting after cattle trampling the field is the usual method of sowing *teff*. In most cases, the seeds are left uncovered, although some farmers pull tree branches over the surface to cover the seeds lightly with soil, in case there is dry spell after sowing. Uncovered seeds are also prone to erosion (water and wind) and bird attack (BoARD, 2000).

Teff is one of the very important cereal crops in Ethiopia where it grows under diverse climatic and soil conditions. *Teff* occupies over 2.8 million hectares which is nearly one-third of the area covered by cereals (CSA, 2010). The crop is the main daily staple food for over 50 million Ethiopians. As the population increases the demand for *teff* will also increase. Unless productivity is improved increase in production will come from area expansion. This will have a negative impact on the environment. Already, farmers in some areas are planting teff where it should not be grown. However, lack of improved cultural practices is among the major production constraints contributing to low productivity of *teff*. Lodging (falling over of the whole plant) is a major problem in *teff* production, reducing yield by 17-25 %. However, under appropriate cultural practices, improved varieties can yield up to 3.4 tons/ha on farmers' fields, indicating that there is an ample opportunity to increase *teff* productivity with high yielding varieties and improved management practices.

Teff is not only a fundamental ingredient in Ethiopian diets, but also an integral part of the national culture (ATA Ethiopia 2009). Unfortunately, without the benefit of worldwide focus, *teff* remains what is often called an "*orphan crop*"; one that has received significantly less international research on breeding, agronomy, mechanization, and processing. As a result, Ethiopian farmers employ very few modern farming technologies or techniques to their *teff* crops, leading to low yields, increased post-harvest losses, and a constraint to national *teff* stocks that have driven prices beyond the reach of many Ethiopian households.

The adoption of more efficient farming practices and technologies that enhance agricultural productivity and improve environmental sustainability is instrumental for achieving economic growth, food security and poverty alleviation in *Tigrai*, Ethiopia. Sawing in line/row planting/ of *teff* was implemented in 2003 with few early adopters in Tigrai in order to increase crop productivity and incomes for small scale farm household. However, its impact on these areas was not known and no effort had been made to evaluate the program and its activities hence creating an information gap that needed to be filed. In spite of the government's efforts to address the issue of low productivity, the raw planting still remains difficult to be practiced by the farmers. This study, therefore, intended to assess the impact of the row planting on agricultural productivity, to assess the opinion of farmers about the new agricultural technology and factors that affect the adoption of new practice in *wereda Tahtay Machew*, Tigrai.

1.3. Research Objectives and Questions

1.3.1. Objective of the study

The general objective of this study is to examine the impact of sowing in line on agricultural productivity in Tahtay Machewu wereda. The specific objectives are:

1. *To investigate the attitude and willingness of the farmers' adoption of sowing in line.*
2. *To evaluate the effect of sowing in line on agricultural income as compared with the traditional sowing practice.*
3. *To explore the main factors that constrains row planting practice.*

1.3.2. Research questions

Based on the objectives listed above, the following research questions are prepared:

1. *What is the attitude and willingness of farmers to adopt row planting?*
2. *Does the practice of row planting have significant impact on agricultural income compare with the traditional sowing practice?*
3. *What are the main factors that constrain adoption and implementation of sowing in line practice?*

1.4. Significance of the study

This study would fill the gap on studies on impact of row planting of teff in agricultural productivity since it is new agricultural technology to our region as well as to our country. This research will provide an insight on the effect of sowing in line on agricultural productivity. In addition, this research is new to be done it will facilitate further researches on this issue. Moreover, this study may address policy implication to foster economic growth in Tigrai, Ethiopia. Therefore, this study may serve as a source of additional information which may be of significant use to policy makers and planners of the wereda Tahtay maychew as well as the region during the implementation of row planting technology.

1.5. Scope of the study

Since it was not possible to cover the whole Tigrai Regional state with the available time and resources, the research was limited the study size and the scope of the problem to a manageable size. Hence, the study focused on the representative sites in wereda Tahtay maychew. The study considers farmers who are practicing row planting of teff and who doesn't practice the new agricultural technology. Substantial qualitative and quantitative information will be gathered on agricultural production, the different aspects of the row planting technologies adopted, problems related with the technology intervention and potential solutions, and reason not to adopt by non-users of the technology

2. CHAPTER TWO: REVIEW OF LITRATURE

2.1. Definition of row planting

Planting with space' involves the growing of plants on a plot of land with sufficient space between each of the plants so that they can develop their roots and shoots more fully. As emphasized by ATA (2012) Crop 'planting with space' starts with growing seedlings in a nursery and planting these in the field with sufficient and equal spacing between each seedling. Or, the seed can be sown in rows with sufficient spacing between the seeds and between the rows.

In Ethiopia, it is the practice with crops such as sorghum, maize and teff that, when these begin to grow, there will be some areas in the field where they are close together and other areas where there are gaps between the plants. Farmers lightly plough and lift the plants out from the densely-growing areas and re-plant them in the gaps. This is a traditional type of 'planting with space'.

2.2. Definition of adoption/participation

Adoption process is the change that takes place within individual with regards to an innovation from the moment that they first become aware of the innovation to the final decision to use it or not. However, as emphasized by Ray (2001), adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not be always practiced by farmers to adopt new technology. Farmers may adopt the new technology by passing the trial stage. In some cases, particularly with environmental innovations, farmers may hold awareness and knowledge but because of other factors affecting the decision making process, adoption may not occur.

Dasgupta (1989) indicate that, the decision to adopt an innovation is not normally a single instantaneous act, it involves a process. The adoption is a decision-making process, in which an individual goes through a number of mental stages before making a final decision to adopt an innovation. Decision-making process is the process through which an individual passes from first knowledge of an innovation, to forming an attitude toward an innovation, to a decision to adopt or reject, to implementation of new idea, and to confirmation of the decision (Ray, 2001).

The rate of adoption is defined as the percentage of farmers who have adopted a given technology. The intensity of adoption is defined as the level of adoption of a given technology. The number of hectares planted with improved seed (also tested as the percentage of each farm planted to improved seed) or the amount of input applied per hectare will be referred to as the intensity of adoption of the respective technologies (Nkonya *et al.*, 1997).

2.3. Technological Change and Agricultural Development

Despite various attempts to transform agriculture by the developing countries, the sector has still remained in its traditional state. The reason behind the low level of agricultural development is introverted policies followed by the governments of these countries over the years. Development strategies of the 1950s and early 1960s gave priority to promote the industrial sector for which agriculture was neglected. The rapid population growth, on the one hand, and the widening gap between the demand for and the supply of food production, on the other, has brought an impetus for agriculture to receive increased attention in the late 1960s.

Therefore in order to reap the benefits that agriculture can provide to the mass of the rural poor in particular and to the national development at large, it is necessary to transform the traditional agriculture into a productive sector (Shultze, 1964) or what Mosher (1966) termed as "getting agriculture moving." Agricultural transformation, therefore, requires appropriate public policy intervention (Yotopoulos, 1967; Halcrow, 1984) so as to generate the surplus produce. Further the formulation of agricultural policy in turn requires a consideration of various interacting factors that include, among others, organization of agriculture, natural factors, institutional arrangements, product characteristics, factor and product markets (Halcrow, 1984; Dejene, 1995).

One of the basic factors in the transformation of agriculture is 'technological change.' Seclar (1993; cited in Dejene, 1995) described that adoption of new technologies, on a regular basis, among others, induce a dynamic growth process that enable the agricultural sector to produce food cheaply, and releasing labor to the non-agricultural sector. Agricultural technology, hence, refers to innovations of new ideas, methods, practices or techniques of production that provide the means of achieving sustained increase in farm productivity (Abate, 1989:19). Anderson (no date) pointed out that adoption of a new technology not previously used in the production process implies technological change, adoption being defined as the act of incorporating something into the production process. It is important to note that the generation of new technology is not suffice by itself but the degree of its diffusion does so. In this regard, Anderson stated that the adoption of technology must be preceded by technology diffusion where the latter term implies the act of making technology available to potential adopters and is then a link between R&D and adoption. Mosher (1966) emphasized that new technology adoption and diffusion alone is not enough to get agriculture moving and thus changes in the institutional, infrastructural, and cultural factors must occur in the process of transformation. Similarly, Nerlove (1993; cited in Dejene, 1995:9) noted the following:

Technology apparently plays a crucial in agricultural modernization, but the process cannot be understood solely in terms of technology. The interactions of technology with a number of social and economic factors have to be taken into *account*.

The need for technology adoption in agriculture, besides increasing factors' efficiency, is to cope with natural hazards faced by the sector. Experiences of many countries showed that sizable proportion of agricultural technology is commodity specific (improved seeds and animal breeds) that are suited only for limited and usually most favourable ecological environments (Anderson, no date). Therefore, areas with poor environments may not have a chance of adopting due to their poor response to the technologies in question.
Agricultural technology includes not only biological and chemical types but also mechanical and management technology. It is within this given framework that agricultural technology should have to be perceived. These technologies can help increasing efficiency in a number of ways. Anderson (no date) described that agricultural technology increase efficiency through increasing production for a given country of one or more resources, or a reduction in the use of resources with constant production, and efficient utilization of other agricultural resources used in the production process. It can be deduced that technological change in agriculture, its diffusion and adoption can substantially induce growth to agricultural production. Agricultural research and extension are the basis for such a process to advance further.

2.4. Factors Affecting Technology Adoption

The objective of the row planting program is to increase farm production and productivity through creation of awareness and technology adoption. However, the adoption decision of farmers and intensity of use of improved technologies are determined by many factors. The factors documented in literature include farming household specific characteristics, available farm resources, access to credit, information and market. For example, Ethiopian Development Research Institute (EDRI) conducted a rural survey in 2001/2002 covering 1920 households in four regions (Tigrai, Amhara, Oromia and Southern People and Nationalities) to evaluate the progress made in adoption and diffusion of agricultural technologies through Participatory Demonstration and Training Extension System (PADETES). The result of the analysis shows that:

- Farmers with larger land holding are more likely to adopt technologies as compared to those with small land holding.
- Older farmers have lower probability of adopting new technologies.
- Information (extension contact) is found to be crucial determinant for technology adoption.
- Literacy level, proximity to extension service center and availability of family labour has shown positive relationship with rate of technology adoption

2.5. Improved technologies and teff yields

Despite the importance of teff in Ethiopia, yields are remarkably low. While in 2012 - 2013, teff land productivity reached 1.4 ton per hectare, this is rather low when compared to other cereals such as maize (3.1 ton per hectare), rice (2.8 ton per hectare) and wheat (2.1 ton per hectare) (CSA 2013). Several factors explain this low yield. First, modern input use in teff production — such as inorganic fertilizer and improved seed—is low. Latest national estimates show that only two percent of teff farmers used improved seeds, although more than one third applied fertilizer for teff production (CSA 2012). Second, plant lodging, to which teff is susceptible, is perceived to be detrimental for teff grain production, especially during the grain-filling period (Berhe et al. 2011). Third, land is repeatedly ploughed before sowing to prepare the seedbed and control weeds, but this leads to increased erosion and lower soil fertility (Tulema et al. 2008; Fufa et al. 2011). Fourth, soil erosion has led to nutrient (mainly nitrogen and phosphorus) deficiencies in the drier areas of the country (Habtegebrial et al. 2007). Finally, there are significant post-harvest and processing losses (Fufa et al. 2011).

Overall, research on improved teff technologies has received limited international attention mainly because of the crop having only local importance (Berhane et al. 2011; Fufa et al. 2011). Not only has international funding for teff research been low, but national research also has been limited with institutions carrying out research on teff being understaffed. The crop therefore suffers from a lack of in-depth knowledge, which complicates extension efforts aimed at increasing teff production (ATA 2013). However, some improved technologies have been identified to stimulate teff productivity. Experiments on genetic improvements and breeding achieved substantially higher teff grain yield (a 34 percent increase) in research settings. However, the improved teff varieties have not been widely accepted, seemingly associated with low consumer demand for the better performing varieties (Teklu and Tefera 2005; ATA 2013). Later studies showed the potential of better land management for enhanced teff production—reduced tillage (Tulema et al. 2008), nitrogen fertilization (Habtegebrial et al. 2007), and water conservation measures (Araya et al. 2012)—but only in research settings.

It has been argued recently that low teff productivity is partly caused by the way farmers sow teff seed. Traditionally, farmers broadcast the seed using a rate of 25–50 kg per hectare (ATA 2013). This practice reduces yields because of the uneven distribution of the seeds, higher competition between plants for inputs (water, light and nutrients), and difficult weeding once the plants have matured (Fufa et al. 2011). As a solution, it has been proposed to reduce seed rates and to plant seed in rows or to transplant seedlings (as is often done for rice, for example). Reducing the seed rate to between 2.5 and 3 kg per hectare allows for reduced competition between seedlings and optimal tillering of the teff plants. By row planting or transplanting the seeds, land management and especially weeding can also be done more readily and the incidence of lodging is reduced (Berhe et al. 2011, Chanyalew and Assefa 2013).

2.6. Response of teff to Sowing Method

Broadcasting as one of the seed sowing methods, and in combination with reduced cultivation offers the advantage of being up to four times faster than conventional ploughing and drilling and is of particular value for sowing large hectare of winter cereals (Ball, 1996). Grass seed fields may be seeded by broadcasting or in rows depending on the available equipment, moisture content and species. Broadcast method of planting is less expensive, uneven seeds distribution, high competition among plants at certain area and no competition at all in other areas takes place in the field, no or less tillering, thin stalk, light and short panicle length and less time taking (Hunt, 1999). It also decreased in water use efficiency and fertilizer efficiency and difficulty of controlling weeds by inter cultivation. In order to avoid uneven stands, improve tillering, improve yield attributing parameters, to reduce lodging and decrease competition among plants, row planting is preferred although it is tedious, time taking and needs qualified person (Hunt, 1999). Row planting will help in controlling weeds, especially mechanical control by inter cultivation and management of the crop and maintaining optimum density of seedlings. Row seeding of germinated seeds could also be done but it is practiced on limited scale because of its costs and difficulty in obtaining implements (Chatterje and Maiti, 1985). Balock et.al.,(2002) indicated that wider spacing had linearly increasing effect on the performance of individual plants as they draw more nut rients from surrounding and more solar radiation for better photosynthetic process which inter produces more effective tiller numbers and longer panicle length per each tillers than dense once. According to Mitiku (2008), there was significant increase in yield components of tef with decreased seed rates from highest to lowest (35, 30, 25, 20, kg/ha). On the other hand, the lodging percentage of the crop was increased by increasing the seed rates.

2.7. Conceptual Framework

Agricultural technology adoption and diffusion patterns often vary from location to location. The variations in adoption patterns were created due to the presence of disparity in agroecology, institutional and social factors. Moreover farmers' adoption behavior, especially in low-income countries, is influenced by a complex set of socio- economic, demographic, technical, institutional and biophysical factors (Feder et al, 1985).

Adoption rates were also noted to vary between different group of farmers due to differences in access to resources (land, labor, and capital) credit, & information and differences in farmers' perceptions of risks and profits associated with new technology. The determinant of degree and direction and degree of impact of adoption are not uniform; the impact varies depending on type of technology and the conditions of areas where the technology is to be introduced (Legesse, 1998).

Farmers' decision to adopt new technologies can also be influenced by factors related to their objectives and constraints. These factors include farmers' resource endowments as measured by (1) size of family labors, farm size and livestock ownership, (2) farmers' socio–economic circumstance (age, and formal education) and (3) institutional support system available for inputs (CIMMIYT, 1993).

In many developing countries, it has become apparent that generating new technology alone has not provided solution to help poor farmers to increase agricultural productivity and achieve higher standards of living. In spite of the efforts of National and International development organizations, the problem of technology adoption and hence low agricultural productivity is still a major concern (CIMMIYT, 1993).

In this study efforts will be made to figure out the impact of sowing in line of tef according to farmers' personal characteristics, accessibilities to different services such as credit, extension, and Psychological factors.

Moreover literature, practical experiences and field observations have confirmed that technology adoption by farmers' can be enhanced in a sustainable manner by understanding those factors influencing the pattern, degree and direction of adoption and strategies through farmers empowering, increasing farmers access to infrastructure, information, credit, field support, etc and acquainting them about how to utilize the technology.

Farmers' participation in technology development, and dissemination strategies as well as result evaluation should be considered, because farmers have long years of farming experience and acquaintance with environmental conditions. The need and interest of farmers' towards agricultural innovations also varies depending on farmers' farming environment, their belief, experience, economic status and their personal background. Therefore, disseminating improved agricultural technologies without consultation of farmers most probably ends with failure.

Practical experiences and observations of the reality have shown that one factor may enhance adoption of one technology in one specific area for certain period of time and may create hindrance for other locations. Because of this reason, it is difficult to develop a one and unified adoption model in technology adoption process for all specific locations. Therefore the type of technology that fits for all should not be accepted by technology users due to their different situations. Hence, the conceptual framework presented in the Figure shows the most important variables expected to influence the intensity of adoption of row planting in the study area.

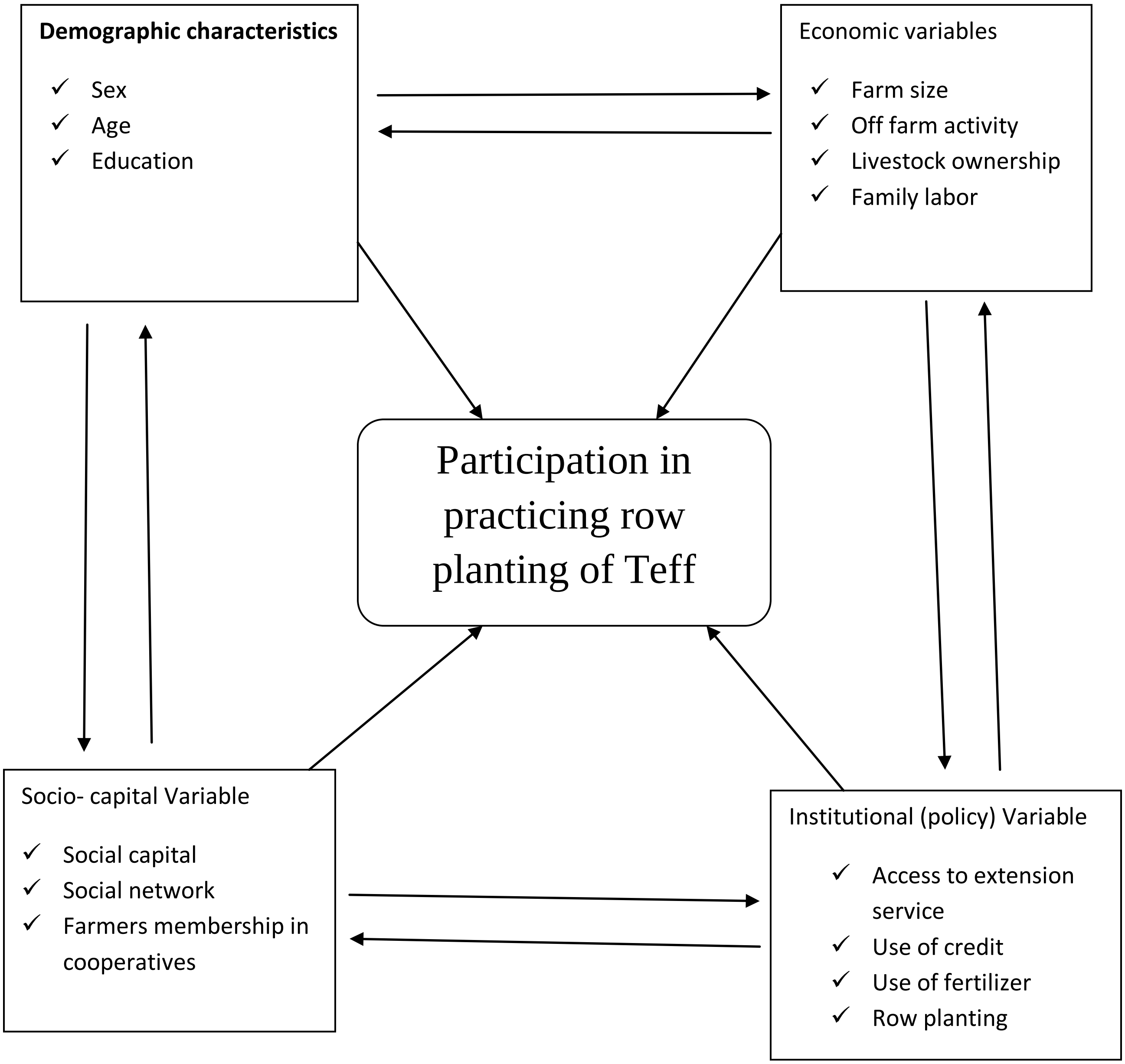

Figure 1. Conceptual framework of the study

3. CHAPTER THREE : RESEARCH METHODOLOGY

3.1. Description of the Study Area

Tahtay maychew wereda is found in the Central Zone of Tigrai Region. Geographically it is located from $13^0$53'27'' and $14^0$20'53'' North Latitude and $38^0$29'58'' and $38^0$39'55'' East Longitude. It is bordered by the *wereda* Medebay Zana in the west, Naeder Adet *wereda* in the north, *wereda* Laelay Machewu in the east, and *wereda* Mereb Leke in the south. It has 19 Tabias and it is considered as one of the region's district with high potential for teff production. The district covers a total land area of 574.68 square kilometers (BoFED 2013).

The altitude in the wereda ranges from 1,500 to 2,420 m.a.s.l,. The woreda mean annual temperature is around 20 ^oC. The climate of the *wereda* is classified into two agro-climatological zones: Midland (weynadega) 70% and low land (kola) 30%. The average annual rain fall of the wereda in the low land ranges from 400 to 500mm and in the Midland (weynadega) ranges from 600 to 700mm. The wereda is characterized by mixed farming system where crop and livestock production are the main activities, where crops play the dominant role in terms of contribution to farmers income.

According to the recent population projection reports (2014E.C), the total number of rural households in 19 rural k*ebeles* in the *wereda* is 25,767. Out of these, 16,797are men headed and 8,970 are women headed households. The total *wereda* population is 118,530, out of which 58,143 are male and 60,387 are female. Economically active population of the *wereda* is 61,921 people out of which, 29,374 are male and 32,547 are female. (BOFED...Annual statistical bulletine 2013 E.C)

Agriculture is the main stay of the district and hence it provides the largest share of the livelihood for the population. However, it is characterized by lack of access to modern technology, market, low productivity, dependency on rainfall and lack of irrigation practice. As a result, the sector remains subsistence in its nature (BoARD, 2013).

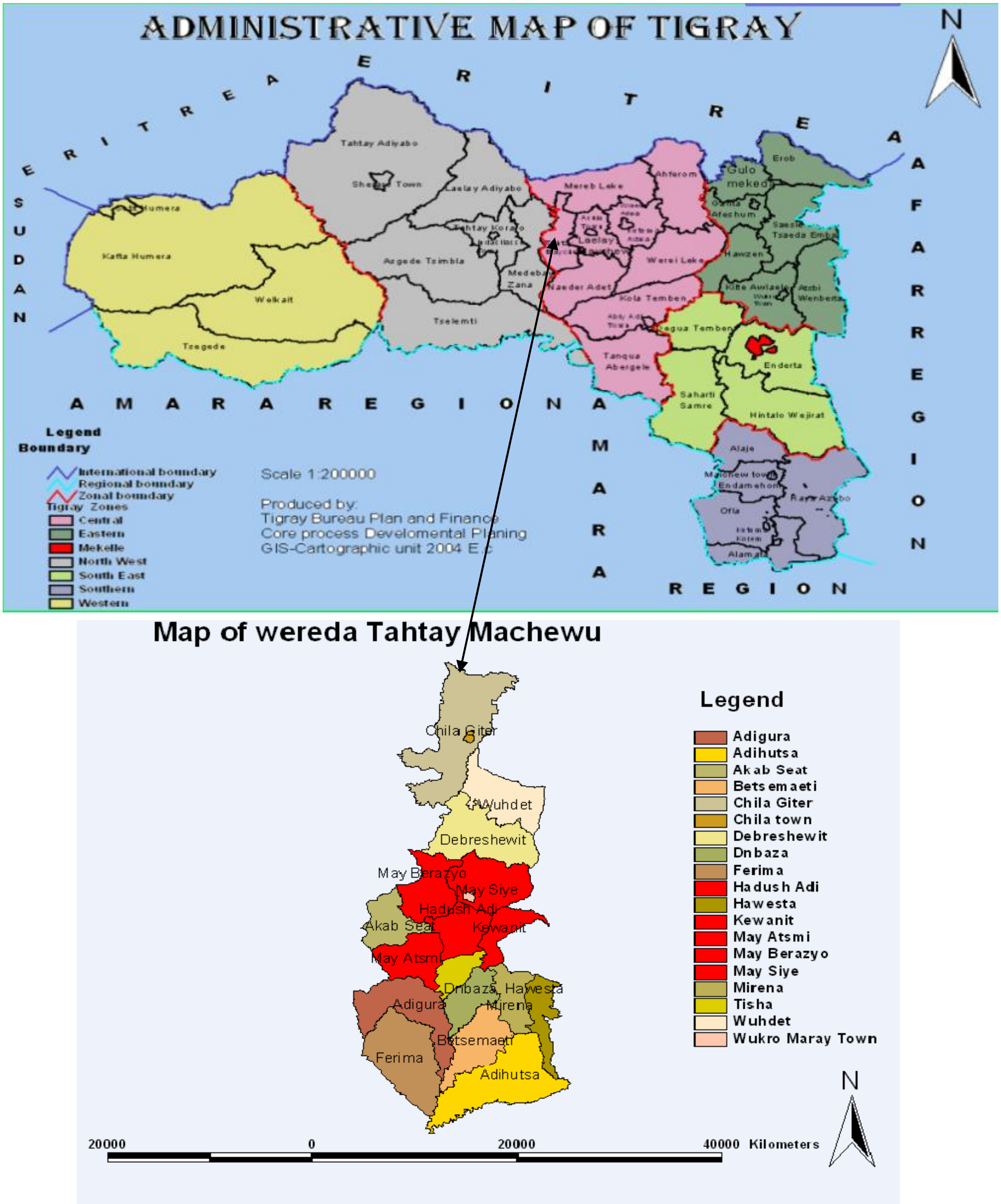

Figure 2. Map of the study area

3.2. Sampling Procedure

To select sample respondents from the *wereda*, three stage stratified sampling technique is employed. In the first stage, *Tahtay maychew wereda* is purposely selected. The fact that this wereda was appropriate because sowing in line of *teff* is practiced widely and *teff* coverage from the total cultivated land in the *wereda* is better than other. The total cultivated area of the wereda is around 18,495.7 hec, out of this 4,221(23%) hec is covered by tef and around 1,714(41%) hec is row planted (BoARD 2014).

In the second stage, using purposeful sampling technique five *Tabias* (*May Berazyo, May Siye, May Atsmi, kewanit and Hadush Adi*) were selected from 19 *tabias* based on their practice of row planting better than others. Hence these *tabias* have both households practicing the row planting and those do not practice row planting.

At last the household heads list was identified followed by a systematic random sampling technique to select sample households from each household category from the *tabia* administration. Households were stratified in to two strata: those households who adopt row planting technology and those farmers who practice the traditional farming system. Then the sample respondents from each stratum will be selected randomly using simple random sampling technique. Based on this multi stage sampling process a total of 300 households from all the 120 adopters and 180 non adopters of row planting were selected on a random sampling basis from 5 *tabias* of *Tahtay maychew wereda*.

3.3. Data Type, source and collection Methods

The advantage of employing qualitative and quantitative methods in research is getting increasing recognition among researchers. It enables to benefit from the insights that the two methods provide when used in combination. Moreover, the most effective evaluation research is the one that combines qualitative and quantitative components (Babbie 2003). Thus, the research strategies employed in this study combine both qualitative and quantitative methods. Qualitative method is used to capture data pertaining farmers attitude and willingness to adopt sowing in line using semi-structured questionnaire. Quantitative data on demographic characteristics and other basic information is collected from sample households using structured questionnaire. Focused group discussion and key in formant data collection tools was also be used. Secondary data was collected from relevant literatures, reports of Agricultural and Rural development offices and other publications.

The interest of the respondents in survey work was an issue given top priority. Farmers may show little cooperation unless their concerns were taken care of very seriously. Therefore, in order to gain their trust, the respondents were carefully informed about the objectives of the survey and the direct and indirect benefits to them. In this regard, chair-persons of the respective rural kebeles were first approached and efforts were made to convince them of the objectives of the study. Farmers were also informed that information related to household and farm characteristics would be kept confidential.

Firstly, the interview schedule was tested at the farm level on 10 randomly selected farm households. In the light of pre-testing, essential amendments was made on such things as ordering and wording of questions and coverage of the interview schedule. Furthermore, the pre-test enable to know whether farmers have clearly understood the interview schedule.

After pre-testing and prior to the final administration of the interview schedule, enumerators were given training and briefings on the objective, contents of the interview schedule and was also acquaint with the basic techniques of data gathering and interviewing techniques and on how to approach farmers. Then using the amended structured interview schedule, primary data was collected by using personal interview technique from sampled farmers. The interview schedule was administered by using trained enumerators. In order to increase the reliability of the survey data and to reduce technical and linguistic problems at the farm level appropriate supervision was made by the researcher

Secondary information that could supplement the primary data was collected from published and unpublished documents obtained from, Tahtay maychew wereda office of agriculture and rural development, Bureau of Agriculture and rural development of Tigrai region and other relevant organizations.

3.4. Data Analysis Techniques

The study employed both descriptive and econometric data analysis techniques. The descriptive analysis is applied to discuss the situation of row planting in the study area .The descriptive analysis was performed using frequencies, means, and maximum and minimum values while the econometric analysis is used to identify the impact of row planting of teff on household income.

3.5. Method of Data analysis

One of the critical problems in non experimental methods is the presence of selection bias which could arise mainly from nonrandom location of the project and the nonrandom selection of participant households that makes evaluation problematic (Heckman et al., 1998). According to Bernard et al. (2010), there are three potential source of bias. The first one is that participant households may significantly differ from nonparticipants in community as well as household level due to observable characteristics (such as geographic remoteness, or a household's physical and human capital stock) that may have a direct effect on outcome of interest. Secondly, the difference arises due to unobservable community as well as household level characteristic. For instance, the existence of a project may be in part driven by particularly dynamic local leaders at community level or individual member of the household special network and ability to understand some new technology. At the household level, a household's expected benefits, its entrepreneurial spirit, or its relationship with other program/project may significantly influence behavior. Thirdly, externalities (spillover effect) exerted by project on nonparticipants. As a result of the above problems, differences between participants and non-participants may, either totally or partially, reflect initial differences between the two groups.

3.5.1. Impact of row planting of teff on household income

To address the observable characteristics Propensity score matching is appropriate to utilize. Choosing an appropriate model and analytical technique depends on the type of variable under consideration (Gebrehiwot, 2008). Here the dependent variable of interest is binary that takes a value of 1 and 0. Assessing the impact of any intervention requires making an inference about the outcomes that would have been observed for program participants had they not participated. The appropriate evaluation of the impact of the program requires identifying the average treatment effect on the treated (ATT) defined as the difference in the outcome variables between the treated households and their counterfactual. Counterfactual refers to what would have happened to the outcome of program participants had they not participated (Rosenbaum and Rubin, 1983; Gilligan *et al.*, 2008).

Access to the impact of sowing in line of *teff* was not randomized. As a result, the impact of sowing in line of *teff* on household income will be estimated using propensity score matching as a method of estimating the counterfactual outcome for sowing in line of *teff* beneficiaries. Estimating the propensity score and making that the balancing condition satisfied is the first step in propensity score matching (PSM) based on observed household characteristics. The magnitude of a propensity score ranges between 1 and 0; the larger the propensity score, the more likely the household is to participate in the Program (Setboonsarng *et al.*, 2008). Variables used in propensity score estimation in this study are age of the household head, sex of the household head, marital status, education status of the household head, Tropical livestock ownership unit (TLU), family size, access to credit service, access to extension agent service, access to irrigation, access to be member of social network, nearness to FTC and use of fertilizer.

According to Rosenbaum and Rubin (1983), let Y^{RP} be the outcome of row planting of *teff* beneficiaries and $Y^{non\ RP}$ outcome of the non- row planting off *teff* beneficiaries. For each household, only Y^{RP} or $Y^{non\ RP}$ is observed, which leads to a missing data problem. In estimating the propensity score, the dependent variable used was participation in the row planting of *teff* practise and let Di denotes the participation indicator equalling 1 with probability of π if the household is practising sowing in line of *teff* beneficiaries and 0 with probability of 1-π otherwise. Let X denotes a vector of observed individual characteristics used as conditioning variables. The most common evaluation parameter of interest is the average impact of the treatment on the treated (ATT) given as:

$$\text{ATT} = \text{E}(\ Y^{RP} - \ Y^{non\ -RP} | D = 1, X) = E(\ Y^{RP} | D = 1) - E(Y^{non\ RP} | D = 1) - - - -3.1$$

This parameter estimates the average impact among sowing in line beneficiaries. The data on row planting beneficiaries identify the mean outcome in the treated state. $\text{E}(\ Y^{RP} | \text{D}_\text{i} = 1, \text{X}\ )$

The mean outcome in the non-row planting beneficiaries $E(Y^{non\ -\ RP} | D_i = 1, X\ )$ is not observed. Let P= $\Pr(D=1|X)$ denote the probability of participating in the practices of sowing in line of *teff*, i.e., the Propensity Score. Propensity Score Matching (PSM) constructs a statistical comparison group (non- row planting of *teff* beneficiaries) by matching observations on sowing in line of *teff* beneficiaries to non- sowing in line of *teff* beneficiaries on similar values of propensity score. Once the propensity score is estimated, the data is split into equally spaced intervals of the propensity score. Within each of these intervals the mean propensity score of each covariate do not differ between participants and non-participants.

The effectiveness of PSM estimators as a feasible estimator for impact evaluation depends heavily on two assumptions (Rosenbaum and Rubin, 1983):

i) Conditional Independence Assumption (CIA):

The CIA states that given a set of observable covariates (X) which are not affected by participation (sowing in line of *teff)*; potential outcomes i.e. is the household income holding are independent of participation assignment. That is the row planting beneficiaries' outcome and non- row planting beneficiaries' outcome is independent of the treatment status. $Y^{RP}, Y^{non-RP} \perp D \mid X$ ——————————————————————————3.2

$E(Y^{RP} \mid P, D_i = 1) - E(Y^{non-RP} \mid P, D_i = 0)$ ———————————————— 3.3

This implies that the non-row planting beneficiaries' outcomes can be used as an unbiased estimation of the counterfactual outcome for the row planting beneficiaries. non-row planting beneficiaries have the same average outcomes as row planting beneficiaries would have had if they did not receive the program, after controlling for all pre-program observable household and community characteristics that are correlated with the program participation and the outcome variable (Gilligan *et al*., 2008).

ii) Common Support Assumption (CSA):

The CSA means that no explanatory variable is allowed to perfectly predict treatment. If the above two assumptions are satisfied, then, after conditioning on propensity score, the $\boldsymbol{Y^{RP}}$ distribution observed for the matched non- row planting beneficiaries can be substituted for the missing $\boldsymbol{Y^{non-RP}}$ distribution for the row planting program.

$0 < P = Pr(D = 1 \mid X) < 1$ ———————————————————————————— 3.4

Matching individuals based on observed covariates might not be desirable or even feasible when the dimensions of the covariates are many. To overcome the problem of dimensionality, instead of matching along X, we can match along P(X). Given that the propensity score is a balancing score, the probability of participation conditional on X will be balanced such that the distribution of observables X will be the same for both participants and non-participants. Consequently, the differences between the groups are reduced to only the attribute of participation assignment, and unbiased impact estimates can be produced (Rosenbaum and Rubin, 1983).

Simultaneous adoption of the above two assumptions [3.2] and [3.4] gives:

$$Y^{RP}, Y^{non-RP} \perp D \mid P(X) ---------------------------3.5$$

As long as outcomes are independent of participation given observables, then they also do not depend on participation given propensity score. Therefore, the multidimensional matching problem is reduced to a one-dimensional problem. The distribution of potential outcomes will be balanced among participants and counterfactuals (Rosenbaum and Rubin, 1983; Heckman *et al.*, 1998).

Building on these underlying assumptions, Propensity Score Matching provides a valid method for estimating $E(Y^{non-RP} \mid D_i = 1, X)$ and obtaining unbiased estimates of ATT (Heckman *et al.*, (1997), Smith and Todd (2001), Smith and Todd (2005)).

Following the Krasuaythong (2008) the parameter of interest here is the average treatment effect on the treated (ATT). Therefore, applying the composite assumption the true ATT, based on PSM can be written as follow:

$$\begin{aligned} ATT\,psm &= E\,p(x)(Y^{RP} - Y^{non-RP} \mid D_i = 1, X) \\ &= E\,p(x)\{E(Y^{RP} - Y^{non-RP} \mid D_i = 1, P(X_i)\} \\ &= E\,p(x)\{E(Y^{RP} \mid D_i = 1, P(X_i)) - E(Y^{non-RP} \mid D_i = 1, P(X_i))\} --3.6 \end{aligned}$$

The perception is that two individual households with the same probability of participation will show up in the participants and non-participants samples in equal proportions on the basis of propensity scores. Where the first term on the right hand side of the above expression (Equation 3.6) can be estimated from the row planting beneficiaries and the second term from the mean outcomes of the matched (i.e. based on propensity score) non- row planting beneficiaries.

The probability of participation in the row planting can be derived by binary response models. Following Todd (1995) cited in Liebenehm *et al.* (2009), who finds that various methods to predict propensity score produce similar estimates, for computational simplicity in this study logit model *was* applied**.**

The propensity score can then be defined as:

$$P(X) = Pr(\ D = 1 \mid X\ ) = F(\beta_1 X_1 + \ \ldots \ldots .. + \beta_i X_i) = F(X\beta) = e^{X\beta} \ --- 3.7$$

Where $F(X\beta)$ produces response probabilities strictly between zero and one. Once the propensity score is estimated, the data is split into equally spaced intervals of the propensity score. Within each of these intervals the mean propensity score of each covariate do not differ between participants and non-participants.

3.5.2. Matching Estimators of the ATT Based on the Propensity Score

Estimation of the propensity scores and making sure that the balancing condition to be satisfied is the first step in Propensity Score Matching techniques (PSM) to estimate the ATT of the outcomes of interest. Even if there are various matching estimators in the literatures to estimate the ATT based on propensity score and can be used separately. For example nearest neighbor matching estimator was used by Gilligan *et al*. (2008) and Yibrah (2010), their consideration in tandem have advantageous because they can be used as a way of measuring the robustness of the results of impact estimates Becker and Ichino (2002). Therefore, in this study the Nearest Neighborhood matching (NNM), Radius matching (RM), stratification matching and kernel matching was employed.

3.5.3. A Simulation-Based Sensitivity Analysis for Matching Estimators

The propensity score is the individual probability of receiving the treatment given the observed covariates: p(X) = P (D = 1|X). If the potential out-come Y_0 is independent of treatment assignment conditional on X, it is also independent of treatment assignment conditional on p(X). The propensity score can thus be used as a univariate summary of all observable variables. As a consequence, if p(X) is known,

The ATT can be consistently estimated as:

$$T_{ATT} = E(\,Y_1 - Y_0 \mid D = 1\,) = E_{\{p(x)|D=1\}}[E(Y_1 \mid P(X), D = 1) - E(Y_0 \mid P(x), D = 0)] \ldots..3.8$$

In practice, p (X) is usually unknown and has to be estimated through some probabilistic model (e.g., probit or logit). Such a model should include all the pre-treatment observable variables that influence both the selection into treatment and the outcome. Higher-order or interaction terms should be included in the specification of the model only if they served to make the estimated propensity score satisfy the balancing property, i.e., to have that within each cell of the propensity score the treated and control units have the same distribution of observable covariates.

3.5.4. Sensitivity analysis

According to Ichino, Mealli and Nannicini (2007) and briefly sketches the sensitivity analysis for propensity-score matching estimators that they propose. One of the central assumptions of the analysis is that treatment assignment is not unconfounded given the set of covariates X, i.e., that Common Support Assumption (CSA) no longer holds. In addition, it is assumed that the CIA holds given X and an unobserved binary variable U:

$$Y_0 \perp\!\!\!\perp D \mid (X, U) \quad \text{3.9}$$

As long as U is not observed, the outcome of the controls cannot be credibly used to estimate the counterfactual outcome of the treated:

$$E(Y_0 \mid D = 1, X) \neq E(Y_0 \mid D = 0, X) \quad \text{3.10}$$

On the contrary, knowing U (together with the observable covariates X) would be enough to consistently estimate the ATT, since:

$$E(Y_0 \mid D = 1, X, U) = E(Y_0 \mid D = 0, X, U) \quad \text{3.11}$$

For expositional simplicity, consider the case of binary potential outcomes: Y_0, $Y_1 \in \{0, 1\}$.Also denote with $Y = D * Y_1 + (1 - D) * Y_0$ the observed outcome for a given unit, which is equal to one of the two potential outcomes depending on treatment assignment. The distribution of the binary confounding factor U is fully characterized by the choice of four parameters:

$$P_{ij} = Pr(U = 1 \mid D = i, Y = j) = Pr(U = 1 \mid D = i, Y = j, X) \quad \text{3.12}$$

with i, j Σ {0, 1}, which give the probability that U = 1 in each of the four groups defined by the treatment status and the outcome value. Note that, in order to make the simulation of the potential confounder feasible, two simplifying assumptions are made: 1) binary U, 2) conditional independence of U with respect to X. Ichino, Mealli and Nannicini (2007) present two Monte Carlo exercises showing that these simulation assumptions do not critically affect the results of the sensitivity analysis.

The simulated U is then treated as any other observed covariate and is included in the set of matching variables used to estimate the propensity score and to compute the ATT according to the chosen matching estimator. Using a given set of values of the sensitivity parameters, the matching estimation is repeated many times and a simulated estimate of the ATT is retrieved as an average of the ATTs over the distribution of U. Thus, for any given configuration of the parameters pij, the sensitivity analysis retrieves a point estimate of the ATT which is robust to the failure of the CIA implied by that particular configuration.

3.5.5. Factors that constrains row planting (Heckman two stage)

The choice to participate or be selected to participate in any program may not necessarily be random. Consequently, selection bias or selectivity bias may exist. Thus, Heckman two stage procedures will be used to control the possibility of selection bias problem. Often people that respond to a survey are self selected implying that they do not constitute a random sample of the general population. Further, a farmer decision to participate or not practicing sowing in line is guided by the perceived utility that will be derived out of engagement in that activity. Utility maximization behavior of a farmer cannot be observed and therefore the decision made is assumed to represent their utility maximization behavior. Heckman (1983) addresses the problem (Madala, 1983) and this approach was employed in unobservable characteristics. The decision to participate will be formulated based on two interrelated choices. First the decision is related to the choice to participate and if the decision to participate is positive, then the second decision is how many acre out of the total (proportion) will be allocated to sowing in line practices. The second choice will come only if the first choice is positive.

In the analysis, a probit equation was specified for whether or not the household is participating (selection equation) and an Ordinary Least Square (OLS) equation for determining the extent in terms of household income (outcome equation) as shown below.

The Probit model is defined as (Long & Freese, 2001: 120):

$$\Pr(y = 1|X) = \Phi(X\beta) ---------------------------- 3.13$$

Where: Φ = notation for standard cumulative normal probability distribution

Xβ = probit score or index which has a normal distribution

X= factors explaining the decision (hh _age, hh _education e.t.c)

β = reflects the changes in the factors on the probability

The solution to the self-selection problem proposed by Heckman (1979) adds a decision equation to the outcome equation. The model consists of the following two equations:

Selection equation $$D^* = \alpha_i Z_i + \mu_i \quad : \quad \begin{Bmatrix} D_i = 0, if\ D^* \leq 0 \\ D_i = 1, if\ D^* > 0 \end{Bmatrix} - - - - - 3.14$$

Outcome equation $$Y^* = x_i\beta + \varepsilon_i \quad : \begin{Bmatrix} Y_i = Y^*, if\ D^* = 1 \\ Y_i\ is\ not\ observed\ \ if\ D^* = 0 \end{Bmatrix} - -3.15$$

Y is only observed if some criterion defined with respect to D is met. The model has two stages; first, a dichotomous variable D determines whether or not Y is observed, Y being observed only if D =1. Secondly, we model the expected value of Y conditional on its being observed. So we observe D, a dummy variable, which is a realization of unobserved continuous variable D * having a normally distributed independent error ε with zero mean and a constant variance. For values D =1 we observe Y, which is observed realization of a second dichotomous variable which has a normally distributed and independent error ε_i with a zero mean and constant variance. The two errors are assumed to have a correlation. In the first equation, the dependent variable is binary and thus binary discrete choice modeling methodology will be captured the practices of sowing in line where a probit maximum likelihood estimator will be used to predict the probability of sowing in line. In the second equation, after the selectivity bias is detected in the second stage inverse Mills' ratio [IMR] which controls self selection bias is included in the outcome equation as a regressor and the equation is estimated using Ordinary least square (OLS) estimates (Heckman 1999). Inverse Mills' ratio [IMR] is the correction term for the bias that arises from selectivity bias problem.

Therefore, the Heckman two stage regression model will be employed in order to control the self selection bias. The model will be employed as follows

$$Y = \beta_i X_i + \alpha_i D_i + \varepsilon_i -3.16$$

Where Y represents the household income, X_i represents a vector exogenous variables that affects the productivity and D_i represents the dummy variable, D=1 if the household practice sowing in line and 0 otherwise. For this model, the effect of the participation on sowing in line is measured by α_i. However, the dummy variable 'D' can't be treated as exogenous if the decision of an individual to participate or not to participate in the sowing in line is based on an individual self selection (Maddala, 1983).

The first stage models a ‘participation equation’, attempts to capture the factors governing participating on sowing in line. This equation is used due to the nature of the data, a fit model to construct a selectivity term known as the ‘Mills ratio’ which is added to the second stage ‘outcome’ equation. If the coefficient of the ‘selectivity’ term is significant then the hypothesis that the participation equation is governed by an unobserved selection process is confirmed. It also enables to verify that the method is relevant to the nature of the data. Moreover, with the inclusion of extra term, the coefficient in the second stage ‘selectivity corrected’ equation is unbiased (Zaman, 2001).

The independent variables include, age of the household, household size, sex of the household head, education background of the farmers, availability of labor and availability of agricultural modern equipments. Distance from FTC and social network are exclusionary variables that can make the Decision equation better. The coefficient α_i measures the situation of sowing in line practices (Maddala, 1992).

The solution to the self-selection problem proposed by Heckman (1979) adds a decision equation to the outcome equation. The model consists of the following two equations:

$$D = \alpha_i Z_i + \mu_i ------------------------3.17$$

$$Y = \beta_i X_i + \alpha_i D_i + \varepsilon_i ------------------------3.18$$

Where the error terms (μ_i and ε_i) are assumed to follow a bivariate normal distribution with mean 0, variances σ_μ *and* σ_ε, and correlation coefficient ρ . The application of ordinary least square estimation using the observed y is biased and the estimates will be inconsistent. Hence, Heckman’s (1979) two-step procedure is usually employed instead.

Therefore, to study the Impact of sowing in line of tef on household income, we should incorporate the underlying process which governs self selection in to the participation on sowing in line method. This is because the impact of sowing in line method has a compound effect on participation and the outcome equations.

3.6. Statistical and Specification Tests

Before executing the final model regressions, all the hypothesized explanatory variables will be checked for the existence of statistical problems such as multicollinearity problems. Basically, multicollinearity may arise due to a linear relationship among explanatory variables and the problem is that, it might cause the estimated regression coefficients to have wrong signs, smaller t-ratios for many of the variables in the regression and high R^2 value. Besides, it causes large variance and standard error with a wide confidence interval. Hence, it is quite difficult to estimate accurately the effect of each variable (Gujarati, 2004; Woodridge, 2002).

There are different methods suggested to detect the existence of multicollinearity problem between the model explanatory variables. Among these methods, variance - inflating factor (VIF) technique is commonly used and is also employed in the present study to detect multicollinearity problem among continuous explanatory variables (Gujarati, 2004). In Gujarati (2004) it was defined that VIF shows how the variance of an estimator is inflated by the presence of multicollinearity (Gujarati, 2004).

Mathematically, VIF for individual explanatory variable (Xi) can be computed as

$$VIF = {}^{1}\!/_{1-R^2} \qquad \text{3.20}$$

Where R^2 is the coefficient of correlation among explanatory variables.

According to Gujarati (2004), the larger the value of VIF indicates the more collinearity among one or more model explanatory variables. As a rule of thumb, if the VIF of a variable exceeds 10, which will happen if a multiple R-square exceeds 0.90, that variable is said be highly collinear (Gujarati, 2004).

Alternatively, we can use the inverse of VIF (1/VIF) called Tolerance (TOL) as a measure of multicollinearity. The closer is TOL of one explanatory variable (Xi) to zero, the greater the degree of collinearity of that variable with the other regressors. On the other hand, the closer TOL of Xi is to 1, the greater the evidence that Xi is not collinear with the other regressors (Gujarati, 2004).

Similarly, contingency coefficient (CC) method was used to detect the degree of association among discrete explanatory variables (Healy, 1984). According to Healy (1984), the discrete/dummy variables are said to be collinear if the value of contingency coefficient (CC) is greater than 0.75 (Healy, 1984). Mathematically:

$$CC = \sqrt{X^2 / n + X^2} \qquad \text{......3.21}$$

Where CC- is contingency coefficient

n - is sample size

X^2 - is chi-square value

3.7. Variables of the Model

The dependent variable for the first stage of the Heckman two-stage procedure is participation in row planting. This variable is a dummy variable (given a value of 1 if the household participates in row planting of teff and 0 otherwise) for the second stage of the model household teff crop income is a continuous variable measured in Birr.

Independent (explanatory) variables: The explanatory variables of importance in this study are those variables, which are thought to have influence on impact of row planting of teff on household income. These include household's personal and demographic variables, economic variables, household socio-psychological variables and institutional variables. These explanatory variables are defined as follows

1. Sex of household head: it is hypothesized that male-headed households are in a better position to pull labor force than the female headed ones. Christina et al., (2001) states that women farmers may need a long adjustment period to diversify their income sources fully and to participate in institutions like row planting. Belayneh (2005) identified that male headed households are higher crop production than female headed households. This variable is entered the model as dummy variable (takes a value of 1 if the household head is male and 0 otherwise) and expected to have a positive relationship with household teff crop income.

2. Age of the household head – a study conducted by Abebaw (2003) indicated that age has significant effect on household crop production. That is, the older the household head, the more experience he has in farming and weather forecasting. As a result, the chance for such household to be crop producer is high. Therefore, it is hypothesized that age of household head has positive impact on household teff crop income. This variable is a continuous variable measured in number of years.

3. Household family size: this variable refers to the size of household members. The existence of a large household size positively influences household teff crop income (Mulugeta, 2002). Therefore, it is expected that household size and teff crop income are positive related. It is a continuous variable measured in the number of adult equivalent.

4. Level of education of the household head: this variable entered the model as a continuous. It is hypothesized that household heads that are literate have a better knowledge of how to make a living. Abebaw (2003) indicated that literate household heads contribute to household teff crop production positively. This variable is a continuous variable and expected to have a positive relationship with teff crop income.

5. Size of cultivated land: Mulugeta (2002) and Ayalew (2003) identified that size of cultivated land has positive impact on household teff crop production. This variable represents the total cultivated land size (both irrigated and rain fed) of a household measured in tsimad. It is hypothesized that farmers who have larger cultivated land are more likely to be high teff crop income than those with smaller area and to participate in row planting. A positive relationship is expected between household high teff crop income and cultivated land size.

6. Total livestock ownership (TLU): This refers to the total number of animals possessed by the household measured in tropical livestock unit (TLU). Livestock is considered as another capital which is liquid and a security against crop failure. Moreover, livestock used for threshing, transporting and etc hence increase production thereby farmers' income. Therefore, this variable will be hypothesized to have a positive impact on farmers’ teff income.

7. Access to Irrigation: it is hypothesized that access to irrigation increases teff crop income as well participation in row planting of teff crop. Therefore, it is assumed that access to irrigation and household teff crop production has a positive relationship. The variable is entered the model as a dummy variable (takes a value of 1 if the household has access to irrigation and 0 otherwise).

8. Access to credit service: it is hypothesized that accesses to credit and teff crop income have positive relationship. The variable is entered the model as a dummy variable (it takes a value 1 if the household has access to credit service and 0 otherwise).

9. Extension services: a dummy variable for extension contact: =1 if the household is contacted by an extension worker in the last two years; 0 otherwise. Farmers having extension contact knows the source and possible benefit of teff crop production and hence expected to be better adopters of row planting. Therefore, it will be hypothesized to affect teff crop production positively.

10. Availability of family labour: it is hypothesized that Availability of family labour and teff crop income have positive relationship. The variable is entered the model as a dummy variable (it takes a value 1 if the household has family labor and 0 otherwise).

11. Membership in social capita: it is exclusionary variables that can make the Decision equation better. It is hypothesized that social capita and teff crop income have positive relationship. It is dummy variable for social capital: =1 if the household is a member in social capital; 0 otherwise

12. Membership in social network: it is exclusionary variables that can make the Decision equation better. It is hypothesized that social network and teff crop income have positive relationship. It is dummy variable for social network: =1 if the household is a member in social capital; 0 otherwise

13. Nearness of the farmers training center: this is also an exclusionary variables that can make the Decision equation better nearness of the households to the FTC is expected to determine both the household's participation in row planting and improving household teff crop production. This variable is a continuous variable measured in kilometer.

4. CHAPTER FOUR: RESULT AND DISCUSSION

This part deals with the result of descriptive statistics and regression output of the empirical model. The analysis was made in the light of the objective of the study. Section 4.1 is about the descriptive analysis of the model variables. Section 4.2 deals about the result of the econometric analysis are presented.

4.1. Descriptive statistics

4.1.1. Sex of the household head

According to the survey result, about 16 percent of the sample households are headed by females and the rest 84 percent are headed by male. When we see the comparison by participation in row planting, out of the 100 participant's households 14 percent are headed by female participants and the corresponding figure for non participants is about 17 percent and about 85 percent are male headed participants.

Table 4.1 Sex of the Household Head

Description	Sample HH	%	participant	%	Non participant	%
Female	48	16	17	14.16	31	17.22
Male	252	84	103	85.83	149	82.77
Total	300	100	119	100	180	100

Source: computed from own survey, 2014.

4.1.2. Age of the household head

The average age of the sample household head is 48 years where the minimum is 25 and the maximum is 80. The average household age of participants in row planting is 46 and the corresponding figure for non participants is 50. From the statistical analysis performed, it is found out that the mean age difference between participants and non participants is statistically significance at 1 percent probability level.

Table 4.2 Ages of the Household Head

Description	Sample HH	participant	Non participant
Mean	48.44	46.09	50.01
Minimum	25	25	25
Maximum	80	76	80
Total	300	120	**180**

Source: computed from own survey, 2014.

4.1.3. Household family size

As can be seen from table 4.3, the average household size of the total sample household was 5 persons, with 1 and 9 being the minimum and the maximum household size respectively. When we compare the average household size between participants in row planting and non participants, the study revealed that households that participate in row planting have more household size than non participant households. Average household size for both is around 5 persons.

Table 4.3 Family size by groups of respondents

family size	**participants**	**%**	**Non participants**	**%**	**Sample household**	**%**
1	0	0	4	2.22	4	1.33
2	7	5.83	12	6.66	19	6.33
3	22	18.33	25	13.88	47	15.66
4	16	13.33	31	17.22	47	15.66
5	21	17.5	39	21.66	60	20
6	28	23.33	38	21.11	66	22
7	9	7.5	21	11.66	30	10
8	17	14.16	9	5	26	8.66
9	0	0	1	0	1	0.33
Total	**120**	**100**	**180**	**100**	**300**	**100**

Source: computed from own survey, 2014.

4.1.4. Level of education of the household head

In the study area, about 49 percent of the sample household heads are found to be illiterate; whereas about 51 percent of the sample household heads have attained education level greater or equal to grade 1. The comparison by the participation in row planting reveals that 29 participants and 119 non participants are found to be illiterate. About 9 participants household heads have attained above grade 8: the corresponding number for non participant's household heads is about 4. The level of education assorts from no education to grade ten.

Table 4.4 Level of education of the household head

Level of education	participants	%	Non participants	%	Sample household	%
0	29	24.1	119	66.11	148	49.33
1	38	31.6	28	15.55	66	22
2	9	7.5	8	4.44	17	5.6
3	14	11.6	9	5	23	7.6
4	11	9.16	8	4.44	19	6.3
5	5	4.16	1	0.5	6	2
6	3	2.5	1	0.5	4	1.33
7	2	1.66	2	1.11	4	1.33
8	3	2.5	4	2.2	7	2.3
10	6	5	0	0	6	2
Total	**120**	**100**	**180**	**100**	**300**	**100**

Source: computed from own survey, 2014.

4.1.5. Size of cultivated land

The land holding of the sample household varies from 0.5 tsimad to 7 tsimad. The average land holding is 2.5 tsimad. The mean land holding for treated group is 3 tsimad and the corresponding figure for control is 2 tsimad. The t-test reveals that mean difference between the two groups is statistically significant at 1 percent probably level. It is quite true that in normal circumstances land size and land productivity are directly and positively related. Taking this into consideration the finding also confirms that size of cultivated has its own influence on participation in row planting of teff crop.

Table 4.5 Size of cultivated land

Description	Sample HH	participant	Non participant
Mean	2.56	3.06	2.06
Minimum	0.5	1	0.5
Maximum	7	7	6
Total	300	120	**180**

Source: computed from own survey, 2014.

4.1.6. Livestock holding

Table 4.6 indicates the mean livestock holding in Tropical Livestock Unit (TLU) for the sample households is 2.73, where the minimum is 0 and the maximum is 8.94. Participants in RP households have a better livestock holding than nonparticipant's households. The mean livestock holding for Participant households is 3.48 TLU and 2.2 TLU for non Participants. The mean comparison for the two groups shows that the difference between the groups with regard to livestock holding is statistically significant at 1 percent probability level. In the communities where agriculture is the main source of economic activity TLU has a significant influence on their agricultural productivity and on total amount of income received.

Table 4.6 Livestock holding

Description	Sample HH	participant	Non participant
Mean	2.73	3.49	2.23
Minimum	0	1	0
Maximum	8.94	8.94	5.8
Total	300	120	**180**

Source: computed from own survey, 2014.

4.1.7. Access to extension service

According to table 4.7, about 93.66 percent of the sample households get extension service. When we compare participants and non participant households' majority of the participant households get support from extension agents when compared to non participants. According to the survey about 99 % participant and 90 % non participant get extension service. Extension service here refers to advice, training, demonstration and distribution of input. About 119 treated group and 162 control groups consult extension agents whenever they need technical advice related with farming activity. From the respondent about 1 % of the participants and 10 % non participants reply they do not get extension service.

Table 4.7 Access to extension service

Description	Sample HH	%	participant	%	Non participant	%
No	19	6.33	120	0.83	18	10
Yes	281	93.66	1	99.16	162	90
Total	300	100	119	100	180	100

Source: computed from own survey, 2014.

4.1.8. Access to credit service

The main source of credit in the study area is Dedebit microfinance. From the sample households 80 percent get credit while 20 % do not get credit due to various reasons. The comparison by participants in row planting disclosed that about 85 % participants and 76.66 % non participants take credit. From participants about 15 % of the sample respondents and from the non participants 23.33 % households said that they don't want credit and the rest complained about high interest rate.

Table 4.8 Access to credit service

Description	Sample HH	%	participant	%	Non participant	%
No	60	20	18	15	42	23.33
Yes	240	80	102	85	138	76.66
Total	300	100	120	100	180	100

Source: computed from own survey, 2014.

4.1.9. Access to irrigation

According to table 4.9, about 32.66 percent of the sample households have the access to irrigation and the rest 67.33 percent does not have the access to irrigation. When we see the comparison by participants in row planting, out of the 100 % participant's households about 32 % have the access to irrigation and the rest 68.33 percent does not have the access to irrigation. If we see the non participants 33.33 % are irrigation users and 66.66 % are non irrigation users.

Table 4.9Access to irrigation

Description	Sample HH	%	participant	%	Non participant	%
No	202	67.33	82	68.33	120	66.66
Yes	98	32.66	38	31.66	60	33.33
Total	300	100	120	100	180	100

Source: computed from own survey, 2014.

4.1.10. Availability of family labour in farm activity

This is a dummy variable referring to farmer's access to family labor. In this study, we consider active family labour as who can participate in agricultural activity in the household. Thus, this variable is expected to positively affect the probability decision to participate on row planting technology. This is because row planting of teff is a labour intensive activity, thus requires high labour. Thus, family labour is the main source of labour force in such cases. According to the survey result, about 69 % of participants and 62.77 % of non participant have family labor. About 31% of participants and 37.22% of non participant farmer's express they do not have family labor.

Table 4.10 Availability of labour in farm activity

Description	Sample HH	%	participant	%	Non participant	%
No	104	34.66	37	30.83	67	37.22
Yes	196	65.33	83	69.16	113	62.77
Total	300	100	120	100	180	100

Source: computed from own survey, 2014.

4.1.11. Membership in social capita

The membership of household heads in local organizations (like edir, equb, marketing cooperative, saving and credit cooperative and Relatives money saving etc) and associations (like peasant, women, and youth associations) are expected to have a positive influence on the farm household's decision to participate on row planting technology. According to the survey result, about 62 % of participants and 57.77 % of non participant farmers from the sample

Wereda responded that they participate in social capital. About 38 % of participants and 42.22 % of non participant farmer's respondent express they do not participate.

Table 4.11 Membership in social capita

Description	Sample HH	%	participant	%	Non participant	%
No	122	40.66	46	38.33	76	42.22
Yes	178	59.33	74	61.66	104	57.77
Total	300	100	120	100	180	100

Source: computed from own survey, 2014.

4.1.12. Membership in social network

According to the survey result, 70% of participants and 64.44% of non participant farmers from the sample Wereda responded that they participate in social network. About 30% of participants and 35.55% of non participant farmer's respondent express they do not participate. Social relationship increases the frequency of discussion about development; enhancing communication for development. This is what the descriptive statistics result reveal, these who have opportunity of participating in social leadership are the once who have high participation in row planting, which could be effect of the discussion and communication they made while they gather to exhaust other social development agendas.

Table 4.12 Membership in social network

Description	Sample HH	%	participant	%	Non participant	%
No	100	33.33	36	30	64	35.55
Yes	200	66.66	84	70	116	64.44
Total	300	100	120	100	180	100

Source: computed from own survey, 2014.

4.1.13. Nearness to farmers training centre from home

The average distance between the household's home and the Farmers training center in kilometer for the sample households is found to be 3.9 km with a minimum of 200 m and a maximum distance of 7 km. According to the survey about 48% participants and about 57% non participants assumes they are living far from farmers training center. Among the respondents about 52% of participants in row planting and about 43% of the non participants assume they are living near to the farmers training center place. The chi-squere result depict that, there was a significance difference between participants and non participants.

Table 4.13 Nearness to farmers training centre from home

Description	Sample HH	%	participant	%	Non participant	%
Far	161	53.66	58	48.33	103	57.22
Near	139	46.33	62	51.66	77	42.77
Total	300	100	120	100	180	100

Source: computed from own survey, 2014.

4.2. Econometric Analysis

4.2.1. Detecting multicollinearity and outliers

One of the assumptions of the multiple regression models is that there is no exact linear relationship between any of the independent variables in the model. If such a linear relationship does exist, we say that the independent variables are perfectly collinear, or that perfect collinearity exists. In practice the more difficult problem is having a high degree of multicollinearity. The variance inflation factors (VIF), the condition index (CI) and contingency coefficient are the most important tests to detect multicollinearity (Pindyck and Rubinfeld, 1991).

The study used the variance inflation factor to check for multicollinearity among continuous variables and contingency coefficient was used to check multicollinearity among discrete variables. According to the test result, multicollinearity was not a serious problem both among the continuous and discreet variables.

4.2.2. The attitude and willingness of the farmers' adoption of row planting.

People have different attitude and willingness to carry out a certain task depending on their historical background, need for change; and social, economic and political environments.

Program participant households were also having different motives to practice the row planting programs and even to select from the options available.

Table 4.14 attitude and willingness of the farmer

Description	participant	%
family	1	0.83
Extension service contact	119	99.16
Total	300	120

Source: computed from own survey, 2014.

Maximum of 2 major driving forces were identified that encourage households to participate in the row planting technology program. Table 4.14 shows that, in comparison with the number of participant, 99.16 percent of the households were participating in the programs because of the awareness creation activities carried out by the wereda officials, Agriculture and rural development officers and development agents. About 1 percent of the households were also joined row planting technology because of the initiation and pressure created by their family members.

The non participants' households were forward different reasons for not participating in the row planting of teff. The reasons for 20.35% respondents were lack of personal interest to participate in row planting. 52.5% respondents said we don't have enough cultivated land size, hence we don't have confidence to sow the available land we have in row and 27.15 respondents said we don't have enough labor and takes time

4.2.3. Econometrics model of Impact Analysis Propensity Score Matching (PSM) Methods

The econometric analysis for the PSM was performed using STATA version 12. Data were collected on 300 observations from Tahtay Maychew wereda. To address the observable characteristics, we use the Propensity Score Matching methods to compute the impact of row planting on their teff crop income.

The researcher estimated the impact of row planting technology on teff income based on cross sectional data available. In this study a non-parametric method propensity score matching (PSM) were also used to address the research question of the impact of row planting on teff crop income. The main goal in using propensity score matching was to identify the average treatment effect on the treated (ATT). In the utilization of PSM in the study, the researcher first estimate a logit regression in which the dependent variable equals 1 if the respondent participate on row planting technology, 0 otherwise and then check the balancing properties of the propensity scores. The balancing procedure tests whether or not adopters and non-adopters observations have the same distribution of propensity scores. When balancing test failed, the researcher tried alternative specifications of the logit model as suggested by Khandker et al 2010. Therefore, specification used in this study is the most complete and robust specifications that satisfied the balancing tests.

Table 4.15 Propensity Score Matching of ATT Effect of NNM, RM, SM and KM

Matching Algorithm	Number of treated	Number of controlled	ATT	Std. Err	t-value
NNM	120	49	1062.667	519.959	2.044**
SM	120	144	1077.854	389.106	2.771***
KM	120	144	1004.172	366.090	2.743***
RM	120	144	1959.602	350.752	5.587***

Where ATT = average impact of treatment on the treated NNM= nearest neighbor matching SM = stratification matching KM = kernel matching and RM= radius matching , *** and ** significant at 1% and 5% level of significant respectively

Source: computed from own survey, 2014.

The PSM estimated result is based on four matching algorithms, the Nearest Neighborhood matching (NNM), Radius matching (RM), stratification matching and kernel matching, are reported in table 4.3. The analysis reveals that adoption of row planting technologies has a significant positive impact on value of teff crop income. Adoption of row planting had increased the teff crop income by about 1,062 Birr per year for NNM, which is significant at 5% probability level, about 1,077 birr per year for SM which is significant at 1% probability level, about 1,004 birr per year for KM which is significant at 1% probability level and about 1,959 birr per year for RM which is significant at 1% probability level, on average compared to the non-adopters. It is the average difference between teff crop incomes of similar pairs of the households belonging to the non-adopters. This indicates that teff crop income for household which adopted row planting technology is significantly higher than the non adopters. This finding is consistent with Menale, et al (2008).

According to Khandker et al 2010 comparing different matching methods results is one approach to check robustness of average treatment effect. Since at least the findings of the already applied above, three matching methods estimation results are quiet similar the researcher concluded that the consistency and robustness of PSM analysis.

4.2.4. A Simulation-Based Sensitivity Analysis for Matching Estimators

The simulation-based sensitivity analysis also used in order to assess the robustness of the estimated treatment effects with respect to deviations from the Conditional Independence Assumption (CIA) Ichino, Mealli and Nannicini (2007).

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Table 4.16. Simulation-Based Sensitivity Analysis Results

Matching Algorithm	Outcome variable	Baseline ATT	Simulated ATT	Std. Err	Pro. Outcome distribution (d)	Outcome Effect	Pro. selection distribution (s)	Selection Effect
NNM	Teff crop income	1,062.7	1,033.2	671.8	0.15	113.8	0.24	4.2
KM	Teff crop income	1,004.2	1,003.5	.	0.1	12.2	0.24	5.0
RM	Teff crop income	1,959.6	1,869.6	290.5	0.1	5.5	0.17	6.8

Ichino, Mealli and Nannicini (2007)

To complement the uncertainty analysis a sensitivity analysis is employed. Sensitivity analysis has been undertaken on the outcome variable Teff crop income using three matching algorithms (i.e Nearest neighbour, kernel and Radius). According to table 4.16, the results of the three matching methods in the outcome variable are consistent and NNM is significant at 5% level of significance, KM is significant at 1% level of significance and RM significant at 1% level of significance. The result shows that the robustness of the baseline ATT with respect to a confounder that is (i.e., a confounder U such that both $d > 0$ and $s > 0$). In addition to this, U is associated to very large selection effect ($\Gamma > 1$) and outcome effects ($\Lambda > 1$) for NNM, KM and

RM. The study revealed that, simulated *ATT* of the outcome variable which is teff crop income is very close to the baseline ATT. This implies that, it is only when U is simulated to provide implausibly large outcome effect i.e. estimates are almost free from unobserved covariates. Consequently, it can be concluded that, the overall the results are remarkably robust and the analysis support the robustness of the matching estimates.

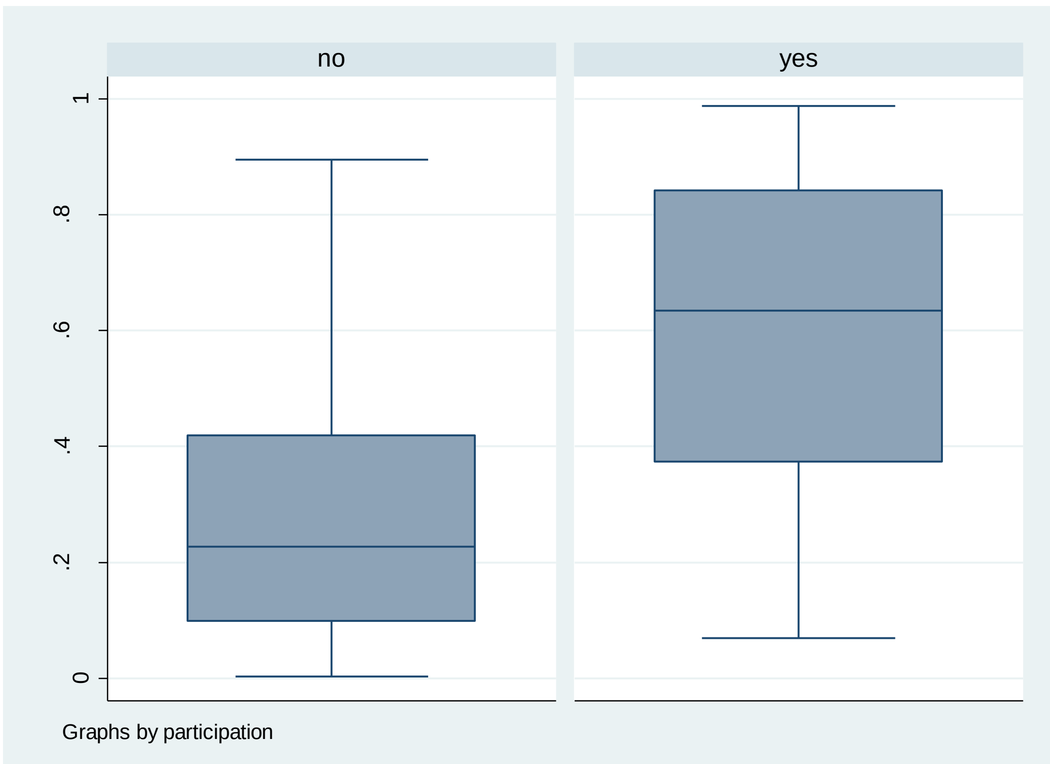

Figure 2. The matching distribution

The estimated propensity score is [.06907621, .98817787] which shows the matching distribution fits well.

4.2.5. Econometrics model of Impact Analysis (Heckman two-stage Model)

The econometric analysis for the Heckman two-stage procedure was also performed using STATA version 12. To address the unobservable characteristics, we use the Heckman two stage methods to compute the difference in outcome of the participants and non-participants on their teff crop income.

The Heckman two-stage procedure was employed in order to control the selectivity bias and endogenity problem and obtain consistent and unbiased estimates. The Heckman model in the first stage predicts the probability of participating in row planting of each household, in the second stage it analyses the determinants of household teff crop income.

4.2.6. Main factors that affects participation in row planting (Heckman selection model)

In this sub section, we treat results concerning teff crop income at household level as well as the socio economic, demographic and other factors that affect the teff crop income behavior of households. We used probit model of estimation to figure out factors having a certain sort of relationship to the program participants. The output for the Probit /participation/ equation shows that six variables determine the probability of participating in row planting technology. These are Level of education of the household head (hh_education), cultivated land size, Tropical Livestock unit (TLU), access to extension service, availability of labor and Nearness to farmers training centre.

Level of education of the household head (hh_education): this variable is significant at 5 percent probability level. It has a positive relationship with participation in row planting technology. The regression analysis shows that being literate has an influence on participating in row planting of teff crop.

Cultivated land size: this variable positively influences participation in row planting. It is significant at 5 percent probability level. The positively relationship implies that farmers, who have more farm size, are most likely to participate in row planting , keeping the effects of other variables constant. In other hand, it indicates as households' farm size increases, the probability to participate in row planting of teff crop increases, ceteris paribus. The study by Poulton et al (2001) suggests that land is an important factor in influencing farmer's decision to produce

Tropical Livestock unit (TLU): this variable shows positive relationship with household participation in row planting technology. It is significant at 1 percent probability level. The justification for this positive relationship could be, if the household head have many TLU specially oxen it makes him or her possible to participate in row planting of teff crop. The main reasons are household head that have many TLU will have high income and he will use his oxen for plowing so it is easy for them to participate.

Access to extension service: this variable showed a positive relationship with participation in row planting of teff. It is significant at 5 percent probability level. The main reasons for possible factor in farmers' decision to participate in row planting technology and their level of production since farmers receive a number of services from extension centres including technical services on its production. Thus, it is expected that farmers who lives near to such service centre are likely to have regular contacts with agricultural experts, hence motivated to participate in row planting of teff technology.

Availability of family labor: The estimated result also shows that, having more working family member increases the probability of participating in row planting of teff. The positive and it is significant at 5 percent probability level confirms that, existence of higher number of working family labor encourages them to participate in the program. The result is expected since family labor is the major source of labor force in the rural area, hence those households who have access to more family labor are likely to participate in row planting of teff. This suggests that labor is among the critical variable in influencing decisions of households to participate.

Nearness to farmers training centre: this is exclusionary variables that can make the Decision Equation better. It has a positive sign as expected and significant at 5 percent probability level. The positive relationship tells us that the nearer the household to the farmers training center, the higher the probability of participating in the row planting on teff crop. When the household is closer to the farmers training center by one kilometer, the probability of participating in the row planting technology increases by 3.9 percent. From the result we can conclude that those households who are situated in nearby places do quickly decide to participate in the program because the extension contact is better.

Table 4.17. Estimation result of the Binary probit model and its Marginal effect

variable	coefficient	P-value	Marginal effect	P-value
hh_sex	-.0186556	0.939	-.0070589	0.939
hh_age	-.0017655	0.849	-.0006666	0.849
hh_education	.1071928	0.031 **	.0404759	0.031**
hh_familysize	-.0174097	0.740	-.0065739	0.740
cultivatedlandsize	.1550555	0.024 **	.0585488	0.024**
tlu	.4933309	0.000 ***	.1862812	0.000***
extensionservice	1.143373	0.042 **	.3173682	0.000***
accesstocredit	.0673359	0.769	.0252469	0.767
useoffertilizer	.0025805	0.991	.0009741	0.991
irrigation_access	-.0645564	0.725	-.0242809	0.724
availabilityoflabor	.3974544	0.043 **	.1466552	0.037**
socialcapital	.2041109	0.261	.0764564	0.256
ocialnetwork	.0064837	0.973	.0024473	0.973
ftc_near	.3713775	0.039**	.1401291	0.038**
cons	-3.6859	0.000 ***	-3.6859	0.000***
Dependent Variable	**participation in row planting of teff (treated)**			
Number of observation	300			
Significance level	0.0000			
Level of significance	Sign			
At 5 percent	**			
At 1 percent	***			

Source: computed from own survey, 2014

4.2.7. Factors affect household teff crop income (Heckman Outcome)

The tef crop income has estimated according to the model put in the methodology part .We note that the dependent variable of the model is the teff crop income. Hence, the regression coefficients measure the unit income change in teff crop income for a unit change in the explanatory variable. Largely in all cases, the statistical significance of the various parameters differs widely across variables and the signs of the estimated variables are as anticipated with reasonable relative magnitudes. As it can be seen from the results of the different regression models, some are statistically significant at 1% and 5% level while others are not significant even at 10% level of significance.

In the outcome equation of the model, four variables are found to be significant factors of household teff crop income. These are: Level of education of the household head, size of cultivated land, Tropical Livestock ownership (TLU) and the inverse Mills ratio (LAMBDA).

Inverse Mills ratio (LAMBDA): According to the model output, the Lambda (inverse Mills ratio) term is significant at 5 percent probability level indicating the presence of selectivity bias. The positively sign suggests that the error terms in the participation and outcome equations are positively correlated. This shows that those unobserved factors that make the household participate in row planting of teff are likely to be positively associated with household teff crop income.

Level of education of the household head (hh_education): this variable is significant at 10 percent probability level. It has a positive relationship with teff crop income. The regression analysis shows that being literate household head has an influence on the increment of teff crop income. The coefficient of the variable shows that as the household gets one more years of education teff crop income of the household increases by Birr 159.15 and this may lead to improved income from household teff crop production.

Size of cultivated land: the regression result shows that this variable has the expected positive sign and it is significant at 1 percent probability level. As the cultivated land size increases, the household becomes able to increase row cropped area on the cultivated land; this may in turn imply increased teff crop income. The coefficient of the variable shows that as the household gets one more tsimad of land teff crop income of the household increases by Birr 1382.068 and this may lead to improved income from household teff crop production.

Tropical Livestock ownership (TLU): this variable is statistically significant at 1 percent probability level. The positive relationship indicates that households with larger livestock holding may have the opportunity to plough at any time with minimum labor cost, especially for oxen. The coefficient of the variable shows that as the household gets one more TLU teff crop income of the household increases by Birr 744.53 and this may lead to improved income from household teff crop production.

Table 4.18. Estimation result of the outcome Equation model and its Marginal effect

variable	coefficient	P-value	Marginal effect	P-value
hh_sex	299.0005	0.480	299.0005	0.480
hh_age	-17.96938	0.310	-17.96938	0.310
hh_education	159.1491	0.085 *	159.1491	0.085 *
hh_familysize	-102.2555	0.257	-102.2555	0.257
cultivatedlandsize	1382.068	0.000 ***	1382.068	0.000 ***
tlu	744.5317	0.002 ***	744.5317	0.002 ***
extensionservice	1538.27	0.306	1538.27	0.306
accesstocredit	265.1797	0.524	265.1797	0.524
useoffertilizer	193.8648	0.630	193.8648	0.630
irrigation_access	84.18839	0.792	84.18839	0.792
availabilityoflabor	471.0404	0.193	471.0404	0.193
cons	-4792.292	0.116	-4792.292	0.116
LAMBDA	1765.957	0.047 **		
Dependent Variable	**Annual teff crop income in birr**			
Selection rule is	Participant=1			
Number of observation	300			
Pro value	0.000			
R-squared	0.7905			
Rho	0.95866			
Level of significance	Sign			
At 10 percent	*			
At 5 percent	**			
At 1 percent	***			

Source: computed from own survey, 2014

Table 4.19 Outcome equation

Teff crop income	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
participation	851.348	155.6234	5.47	0.000	545.0247	1157.671

Source: computed from own survey, 2014

Following the above result the study also runs the Ordinary Least Square (OLS) model to compare the result of the estimate with the Heckman two- step procedure. As expected the model result identified that Level of education of the household head (hh_education), cultivated land size, Tropical Livestock unit (TLU), access to extension service, availability of labor are significant determinant of household teff crop income. But the size of the coefficient for the Heckman two-step procedure is about higher than that of the OLS regression outcome result. Thus, using OLS regression model underestimates the impact of row planting to teff crop income.

Heckman two stage outcome results revealed that the participant households have on average 851.63 birr per year more than the control group in teff crop income per year. The reason for having better income is farmers participating in row planting of teff crop;

To sum up, the overall evaluation of the study conferred that by the impact of row planting on teff crop income of the household, the treated groups are in better position than the control group. This implies the practicing in row planting of teff crop has significant effect than the traditional sowing practices in terms of reducing seeding rate and increasing teff crop productivity.

5. Chapter Five : summary and Policy Implication

This section summarizes the major findings of the study and proposes recommendations for policy purpose. Section 5.1 is conclusion of major findings and Section 5.2 is Policy recommendations.

5.1. Summery of major findings

Teff is among the most widely grown cereals in Ethiopia. The crop is a staple diet of the majority of the population and the most widely planted by farmers. While production and productivity of the crop have increased over time, demand has risen faster and so the price of teff has gone up in recent years. However, the productivity of the crop is low at around 12 q/ha, with the highest productivity farmers achieving 25 q/ha (ATA, 2012).

This paper aims to analyze the impact of row planting of teff on farm household income in wereda Tahitai Maychew, Tigrai regional state. In the choice of parameters covered in the analysis, we were guided by the data available derived from household survey in March, 2014 and carried out propensity score matching for observable characteristics and Heckman two stage samples selection model of estimation is also implemented in order to capture the selectivity bias. In the descriptive analysis of the data set indicates the sample survey involved a total of 300 sample households of which 120 households are from treated and 180 households from control groups. Comparing among groups the high share take by control group which accounts 60% and the share of treated group 40 %.

To carry out this research, one Wereda and one crop (teff) is selected based on different reports, discussion with professionals and researchers experience in the region. Then from this Wereda 5 Tabias were selected based on their relative potential and accessibility. Consequently, 300 sample farmers were randomly selected for interview. In addition to interview of sample farmers using survey questionnaires, different quantitative and qualitative information were collected from different organizations and through focused group discussion in order to have clear vision of the situations.

Based on in this research it is found that households who adopt RP are better off in teff crop income. That means the average value of teff crop income from adoption of RP is around 1,062

Birr per year for NNM, about 1,077 birr per year for SM, about 1,004 birr per year for KM and about 1,959 birr per year for RM higher than those households that did not use the technology. This might be due to the fact that adopting RP increases teff crop yield by reducing seeding rate from 30 Kg to 5Kg/ha and by reduced competition for water, sunlight, and soil nutrients. At sowing the very small quantity of seed makes it difficult to control population density and its distribution. This remains true whether one sows the seed by hand, uses a sower or a seed driller. The plants stand unevenly after germination and have a nutrient efficiency use of the crop and crop yield. Owing to scattered plants, farmers find it difficult to use mechanical weeding implements and are forced to either hand-weed or use chemicals.

In the other hand multivariate analysis is performed using the Heckman two- stage procedure. The Heckman two –stage procedure is implemented in order to capture the selectivity bias to explore the main factors that constrain sowing in line practice on teff crop production. Moreover, the first stage of the model removes the problem of endogenity since it considers participation in row planting as a dependent variable.

In the first stage of the Heckman two-stage procedure the six variables found to determine participation in row planting: level of education of the household , size of cultivated land , TLU, access to extension service, availability of family labor and nearness to FTC were significant and have positive relationship with participation in row planting.

In the second stage of the Heckman two-stage procedure the lambda term which confirms the presence of self selection was significant at 5% probability level indicating the presence of selectivity bias. After the model corrects for the bias due to some unobservable factors, level of education of the household, size of cultivated land, Tropical Livestock ownership and the inverse Mills ratio are found to determine household teff crop income.

To summarize, the treated groups are better than the control groups significantly. The sensitivity analysis also shows that the estimates are almost free from unobserved covariates. Consequently, it can be concluded that, the overall the results are remarkably robust and the analysis support the robustness of the matching estimates. This implies the row planting practices of teff crop has significant effect in the peoples of Tahtay maychew wereda in terms of teff crop yield and income.

5.2. Policy recommendation

There are different sowing method practices going on rural area of Tigrai. However, there is promising practices in some area while less than the expectation in somewhere else. The reason for this success and failure depend on various factors. Among the main reasons, lack of awareness and commitment to implement the row planting by farmers and other principal agents are the key factors.

It is better to encourage row planting technology adoption because the results of this study signify that application of row planting technology; increase substantially both the yield and income of adopters. Nevertheless, the number of adopters and the cropped area under row planting is considerably low to show greater impact on the overall increase of productivity. Therefore, the following measures are recommended:

a) It is necessary to encourage farmers to apply row planting by introducing several measures
b) Increase the income of farmers that grow teff through introducing new seed varieties suitable to the local condition.

In addition to this farmers should have to be aware that lodging is the cause of significant yield loss in teff. One immediate intervention that might help reduces lodging in tef is the breeding of teff lines that are less susceptible to lodging. Planting at a reduced seed rate and in rows has also demonstrated that lodging can be reduced.

The most important problem in practicing row planting of tef crop is its labor requirement and the associated costs. Thus, immediate demonstration of available technologies and practices that help reduce work burden on farmers is essential. This include testing and promotion of technologies such as mouldboard plough that reduce tillage, promotion of line sowing of tef together with the row planter so as to increase yield and reduce weed infestation and associated costs of weeding.

In the first stage of the Heckman two-stage procedure the following variables are found to determine participation in row planting: hh_education, cultivated land size, TLU, access to extension service, availability of family labor and FTC near

Level of household education is significant and positively affects participation in row planting of teff crop. Therefore, formal education enhances farmers' ability to perceive, interpret, and respond to new events in the context of risk.

Cultivated land size significant and positively affects participation in row planting of teff crop. However, there may not be a possibility of expanding cultivated land size. Therefore, households should get trainings and different extension supports to practice row planting of teff confidentially.

Ownership of TLU is significant and positively affects participation in row planting of teff crop. Therefore high ownership of TLU means they have a good income. Hence, household must be trained cost and benefits of row planting in their livelihood.

Access to extension service is significant and positively affects participation in row planting of teff crop. An extension agent contact farmers individually and in the group but it is not adequate.

Availability of family labor is significant and positively affects participation row planting of teff crop. This is because having more working family member increases the probability of participation. It is household specific factors in determining smallholder farmers' participation status.

Nearness to farmers training centre is significant and positively affects participation in row planting of teff crop. This is because farmer who are near to FTC are advantageous to learn from FTC exemplary practices and the development agent spent more time to visit. Therefore the extension service frequencies of visits should increase for the farmers who are far from FTC.

In the second stage of the Heckman two stage the ff variables were significantly determine teff crop income.

Level of education of the household head is significant and positively related to teff crop income indicating being literate improves teff crop income**.** The transfer of knowledge and information concerning to increase teff crop income is very crucial.

Size of cultivated land is significant and positively related to teff crop income indicating larger farm size improves teff crop income. However, there may not be a possibility of expanding cultivated land size. Therefore, household must be trained to improve productivity.

Ownership of Tropical Livestock is significant and positively related to teff crop income. Therefore, efforts aimed at promoting teff crop production by farmers should take the importance of additional finance to teff producer farmers for purchase of farm oxen.

The introduction of the above measures into the picture of technology adoption, therefore, could enhance the number of adopters and the cropped area under row planting technology. Hence, expansion in the level of technology adoption would consequently result in substantial agricultural productivity and income on a sustainable basis.

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APPENDICES

Title: The impact of row planting of teff crop on rural Household income

(The Case of Tahtay Maychew wereda, Tigrai, Ethiopia)

Dear Respondents:

I, Yonas Berhe, am prospective graduate of Masters of Science in Development policy analysis in Mekelle University, College of Business and Economics, dealing with my Master's thesis. So I would like to assure you that this questionnaire is used only for the academic purposes. Thank you for your cooperation

Thank you

General Instructions to Enumerators

i. Make brief introduction to the respondent before starting the interview (greet them, tell your name, get her/his name, and make clear the purpose and objective of the study that you are undertaking).
ii. Please ask the question clearly and patiently until the respondent understands.
iii. During the process put the answers of each respondent both on the space provided and encircle the choice or tick mark as required

General information

Date of interview:___________________________

1. Name of the respondent:____ HH ID _________________

Male/Female: ___________; Age: _____years; years of education: _________

Kushet_________________; Village (Tabia) _________________;

District ________________;Zone_______________Region: ______________________

2. Name of the Interviewer:____________________________________Sign:________________________________

Part one: Household Demographic status

#	Name	Age(Years)	Sex 1=Male2=Female	Education level	Skill 1. Carpenter 2. Black smith 3. House builder	Relationship to the respondent	Occupation: [1] education; [2] farming own land; [3] labor for other farmers; [4] non-farm casual work; [5] small trade/enterprise [4] regular job; [5] retired	Is the member available for work on the household farm? [a] full time; [b] part time; [c] not at all
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								

Module II. Technological adoption

1. Have you ever heard about sowing in line of teff in the past? 1) Yes 2) No (if yes go to question # 2)

2. Where do you get that information?

I. Extension agents

II. Friends and families

III. Neighbors

Iv. Social network sources

v. Tabia administration

vi. Others (please specify)

3. As a household hear do you adopt row planting technology? 1) Yes 2) No if yes since when you adopt years -------- if no go to question # 4

4. Reasons for not adopting row planting of tef

1. It requires labor time
2. It takes time when plowing and sowing in line
3. It is low productive than traditional sowing practices
4. Other specify---------------

5. Do you face labor shortage problem to practice row planting? 1) Yes 2) No

6. If yes, how do you solve labor shortage problem?

1) By hiring 2) Asking for cooperation 3) All 4) Others (Specify) -------

7. Does your father is member of any social affairs 1) yes 2) no

8. If your answer is yes to Q. 7 in which social group

1. Equb 2. Edir 3. Social network 4. Other, specify …………………

9. Do you get enough service from agricultural agents?

1. Yes 2. No

10. Since When do you get extension service in years …………………………….

11. Does your home near to the farmers training center (FTC)?

1. Yes 2. No

12. How many km is the FTC far from your home -------------?

13. Do you get credit access in your locality?

1. Yes 0. No

Part Three: row planting contribution towards Tef production

3.1 Do you think that adoption of row planting has a positive impact on Tef crop production? (Put √ mark)

1. Yes------------ 2. No------------

3.2 If your answer is yes, what are the positive impacts of adoption of sowing in line of tef that you have seen? (Put √ mark)

1. Increased household income-----
2. Reduce fertilizer consumption---
3. Minimizes seeding rate --------
4. Other specify-----

3.3. How many times do you produce within a year?

1. before adoption row planting ------
2. after adoption of row planting -------

3.4. The household income Source before adoption of row planting (put √ mark)

1. Sales of vegetables------
2. Wage ------------------------
3. Rent of own land -------------
4. Sales of tef ---------------------
4. Sales of other cereals-----------
5. Others, Specify-------

3.5 Other income source (before and after irrigation schemes)

Income source	Before sowing in line		After sowing in line		Remarks
	Quantity	Value in birr	Quantity	Value in birr	
Wage/ Salary					
Sales of tef					
Rent of own land					
Cattle rent/sales					
Beehive					
Sales of vegetables					
Sales of other cereals					
Others					

PART FOUR: INCOME FROM AGRICULTURAL PRODUCTIVITY

4.1. Do you have cultivated land?

1. Yes 0. No

4.2. If your answer for number 4.1 is yes, how many hectares do you have?____________________

4.3. Crop income from rain fed farm land in 2005/2006 E.c agricultural season?

Type of crops	Cultivated Area (in tsemad)	Yield in Qt.	Estimated value in birr	Income from crop sale
A. Grain/cereals				
Wheat				
Maize				
Sorghum				
Tefe				
Barley				
Kerkaeata				
Dagusha				
Aeares				
Oil seeds				
Others				
B. Vegetables				
Onions (KeyihShingurti)				
Tomatoes				
Potatoes				
Green pepper				
Tiklilgomen				
Garlic				
Karot				
Keysir				
Duba				
Total				

4.4. Crop income from irrigated land

Type of crops	Cultivated Area (in tsemad)	Yield in Qt.	Estimated value in birr	Income from crop sale
Vegetables				
Onions (KeyihShingurti)				
Tomatoes				
Potatoes				
Green pepper				
Tiklilgomen				
Garlic				
Karot				
Keysir				
Duba				
Total				

PART FIVE: LIVESTOCK PRODUCTION

5.1. Are you engaged in livestock rearing? 1. Yes 0. No

5.2. What was your income from livestock and its products in 2005/2006 E.c agricultural season?

		Total owned	Estimated Price in birr	Income from sales	Income from rent	Total income
Cattle	Oxen					
	Cows					
	Heifer					
	Bull					
	Calves					
	Total					
Sheep and Goat	Sheep					
	Goat					
	Chicken					
	Total					
Marines	Camel					
	Donkey					
	Mules					
	Horse					
	Total					
Animal product	Milk					
	Cheese					
	Butter					
	Eggs					
	Honey					
Total						

5.3. Miscellaneous categories of income

Item	**Income in birr**
Agricultural wage	
Non-agricultural wage	
Self-employment in own businesses	
Pensions	
Remittances	
Food for work	
Safety net program	
Others	
Total	

PART SIX: Access to and utilization of farm inputs for tef crop production

6.1 Which agricultural inputs do you use for Tef crop production and what are the sources?

Type of input	Specific Name	Source(tick)		
		Market	BoARD	Cooperatives
Improved seed of tef				
Local seed of tef				
Fertilizer	DAP			
	Urea			
	Other/ mixture/			
Chemicals	Herbicide			

	Fungicide			
	Insecticide			
Others(Specify)				

7. **PART SEVEN: HOUSEHOLD FOOD EXPENDITURE**

7.1. Cereals

Type of food	Total expenditure on month February			From Agricultural production			From market /bought/			From support		
	Qut.	Measu.	Price in(br.)	Qut.	Measu.	Price in(br.)	Qut.	Measu.	Price in(br.)	Qut.	Measu.	Price in(br.)
Sorghum												
Tef												
Wheat												
Kerkaeata												
Barley												
Maize												
Rise												
Millet												
Dagusha												
Total cost												

Codes: 1 = for kilogram 2 = for Milk 3= for shember

7.2. Oilseeds

Type of food	**Total expenditure on month February**			**From Agricultural production**			**From market /bought/**			**From support**		
	Qut.	**Measu.**	**Price in(br.)**	**Qut.**	**Measu.**	**Price in(br.)**	**Qut.**	**Measu.**	**Price in(br.)**	**Qut.**	**Meas u.**	**Price in(br.)**
Beans												
Pea												
Birshen												
Lentils												
Seber												
Sufe												
Adengor/soybean												
Dekoko												
Total cost												

7.3. Vegetables

Type of food	Total expenditure on month February			From Agricultural production			From market /bought/		
	Qut.	**Measu.**	**Price in(br.)**	**Qut.**	**Measu.**	**Price in(br.)**	**Qut.**	**Measu.**	**Price in(br.)**
Onions(KeyihShin gurti)									
Tomatoes									
Potatoes									
Tiklilgomen /cabbage/									
Garlic/tseda-shingurti/									
Keysir									
Duba									
Karot									
Total									

7.4. Fruit

Type of food	Total expenditure on month February			From Agricultural production			From market /bought/		
	Qut.	**Measu.**	**Price in(br.)**	**Qut.**	**Measu.**	**Price in(br.)**	**Qut.**	**Measu.**	**Price in(br.)**
Zeythun									
Lemon									
Tringo									
Papaya									
Avocado									
Orange									
Total cost									

7.5. Food spice

Type of food	Total expenditure on month February			From Agricultural production			From market /bought/		
	Qut.	Measu.	Price in(br.)	Qut.	Measu.	Price in(br.)	Qut.	Measu.	Price in(br.)
Piper									
Green piper									
Seseg									
Korerima									
Salt									
Zingble									
Tselimkemem									
Total cost									

7.6. Oil, Meat, & other animal products

Type of food	Total expenditure on month February			From Agricultural production			From market /bought/		
	Qut.	Measu.	Price in(br.)	Qut.	Measu.	Price in(br.)	Qut.	Meas u.	Price in(br.)
Butter for food									
Butter for hair									
Beef(keftiSiga)									
Chicken (Dero)									
Eggs									
Mutton (nay begiesiga)									
Milk and milk product									
Total cost									

7.7. Drinking and other Expenses

Drinking Expenses		Other Expenses	
Type	**Total expenses**	**Type**	**Total expenses**
For local beer (tela)		Honey	
For tej		Sugar	
Alchol		Milk powder	
Beer		Packed foods	
Coffe			
Soft drink			
Total cost		**Total cost**	

PART EIGHT: NON-FOOD EXPENSES

8.1. Education Expenses		**7.2. Clothe Expenses**	
Type of expenses	**Total expenses for the past six months 2004 e.c**	**Type Expenses**	**Total expenses for the past six months 2004 e.c**
Exercise book and books		Cloth for parents	
Pen and pencils		Cloth for other members of the household	
Transport		Shoe for household	
Uniform for school cloth		Frash	
Other costs		Bed sheet	
		Medical treatment	
Total cost		**Total cost**	

8.1. Sanitary Expenses		**7.2. petrol, wood and light Expenses**	
Type of expenses	**Total expenses for the past six months 2004 e.c**	**Type Expenses**	**Total expenses for the past six months 2004 e.c**
For hair dressing		Insect sides	
For hair cutting		Petroleum	
Soap for cloth cleaning		Matches	
Soap for bath		Candle	
Powder soap/Omo/		Battery	
Cosmetics		For Power	
Perfume			
Total cost		**Total cost**	

8.1. Other Expenses	
Type of expenses	**Total expenses for the past six months 2004 e.c**
Gift for baggers /poor/	
Contribution for societies	
Contribution for association membership	
Gift for church	
Kristina	
Wedding	
Teskar	
Edir	
Total cost	

PART NINE: Intensity of participation (adoption) of row planting using tef variety

9.1. Do you think adopting sowing in line of tef is making (will make) a contribution to improvement in your livelihood? Yes= 1, No=0

9.2. If yes to Q. 9.1 in what ways?

____

9.3. If No to Q. 9.1, why not?

____

9.4. Which Method of sowing do you think is most promising in your community?

1. Broadcasting 2. Row planting 3. Both

9.5. Why?

____

9.6. In the last two years production season what kind of tef seed varieties did you use?

1) Local 2) improved/ koncho/ 3) both

9.7. Which method of sowing you used in wheat crop production?

1) Row planting 2) Broadcasting 3) Both 4) transplanting

9.8. If your answer is row planting, to which variety you used this method?

1) Local 2) improved / Koncho/ 3) Both

9.9. Did you apply fertilizer in tef crop production? 1) Yes 0) No

9.10. If your answer is yes, to which variety you applied fertilizer?

1) Local 2) improved / Koncho/ 3) both

9.11. If your answer is yes, which kind of fertilizer you used?

1) DAP 2) Urea 3) both

9.12. If you did not apply fertilizer in Tef crop production, what is your reason?

Type of fertilizer not applied yet ______________________

Reason for not applying ____________________________

Checklist used for conducting focused group discussion.

As you probably know, agriculture office is trying to popularize an improved technology, which should significantly increase yields. The office is also providing best practices from other areas who adopt row planting of tef. Even Agricultural agents are also supporting the farmers in different dimensions. However,

Most of the farmers are not adopting row planting .why?

Why are so few farmers adopting the row planting?

Is the row planting make profitable to farmers?

Do the farmers experienced difficulty in practicing row planting?

What are the general impressions about the row planting?

Can you get good quality production inputs of improved wheat seed?

How do you see the recommended seeding and fertilizer application rate?

Did farmers in this area faced disease problem in improved wheat seed production?

Which method of sowing did you use in tef production and why?

Which one of the variety (local or improved/koncho/) you prefer in tef cultivation and why?

Annex table 2 Econometric result of using propensity score matching (PSM)

```
****************************************************

Algorithm to estimate the propensity score

****************************************************

The treatment is participation

  Participation |      Freq.     Percent        Cum.

------------+-----------------------------------

         no |        180       60.00       60.00

        yes |        120       40.00      100.00

------------+-----------------------------------

      Total |        300      100.00

Estimation of the propensity score

Iteration 0:   log likelihood = -201.9035

Iteration 1:   log likelihood = -150.32612

Iteration 2:   log likelihood = -146.22475

Iteration 3:   log likelihood = -145.96304

Iteration 4:   log likelihood = -145.95881

Iteration 5:   log likelihood = -145.95881

Logistic regression                               Number of obs   =        300

                                                  LR chi2(14)     =     111.89

                                                  Prob > chi2     =     0.0000

Log likelihood = -145.95881                       Pseudo R2       =     0.2771

------------------------------------------------------------------------------

participat~n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]

-------------+----------------------------------------------------------------

  _Ihh_sex_1 |  -.0859748   .4108826    -0.21   0.834      -.89129    .7193403

      hh_age |   -.004949   .0162868    -0.30   0.761    -.0368707    .0269726

hh_education |   .1691699   .0850191     1.99   0.047     .0025354    .3358043

hh_familys~e |  -.0315919   .0894777    -0.35   0.724    -.2069649    .1437812

cultivated~e |   .2666227   .1153706     2.31   0.021     .0405005    .4927448
```

```
         tlu |   .8264252   .1339883     6.17   0.000     .5638131    1.089037
_Iextensio~1 |    2.02083   1.098448     1.84   0.066    -.1320887    4.173748
_Iaccessto~1 |   .1570316   .3985782     0.39   0.694    -.6241672    .9382305
_Iuseoffer~1 |   .0273854   .4050202     0.07   0.946    -.7664397    .8212104
_Iirrigati~1 |  -.1591825   .3134207    -0.51   0.612    -.7734757    .4551106
_Iavailabi~1 |   .6767057   .3351581     2.02   0.043     .0198079    1.333603
_Isocialca~1 |    .340569   .3084102     1.10   0.269    -.2639038    .9450419
_Isocialne~1 |  -.0002029   .3322034    -0.00   1.000    -.6513096    .6509038
    ftc_near |   .6475507   .3062962     2.11   0.035     .0472211     1.24788
       _cons |  -6.187461   1.550344    -3.99   0.000    -9.226079   -3.148843
------------------------------------------------------------------------------
Note: the common support option has been selected
The region of common support is [.06907621, .98817787]
Description of the estimated propensity score in region of common support
                 Estimated propensity score
-------------------------------------------------------------
      Percentiles      Smallest
 1%     .0782248       .0690762
 5%     .1021122       .0759625
10%     .1297531       .0782248       Obs                 264
25%     .2232109        .082264       Sum of Wgt.         264
50%     .4127513                      Mean           .4492928
                        Largest       Std. Dev.      .2645273
75%     .6579699       .9710163
90%     .8554118       .9847771       Variance       .0699747
95%     .9360412       .9875838       Skewness       .4222548
99%     .9847771       .9881779       Kurtosis       1.974592
******************************************************

Step 1: Identification of the optimal number of blocks
```

Use option detail if you want more detailed output

****

The final number of blocks is 5

This number of blocks ensures that the mean propensity score

is not different for treated and controls in each block

****

Step 2: Test of balancing property of the propensity score

Use option detail if you want more detailed output

****

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	participation no	participation yes	Total
.0690762	44	12	56
.2	51	21	72
.4	35	19	54
.6	12	33	45
.8	2	35	37
Total	144	120	264

Note: the common support option has been selected

****

End of the algorithm to estimate the pscore

****

. xi: attnd teffcrop_income participation, pscore(ppscore) logit index comsup bootstrap reps(50)

```
 The program is searching the nearest neighbor of each treated unit.

 This operation may take a while.

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

Bootstrapping of standard errors

command:     attnd teffcrop_income participation, pscore(ppscore) logit index comsup

statistic:   r(attnd)(obs=300)

Bootstrap statistics

Variable |   Reps   Observed       Bias   Std. Err.   [95% Conf. Interval]

---------+-------------------------------------------------------------------

     bs1 |     50   1062.667  -11.86974   519.9594    17.76912  2107.564  (N)

         |                                           -200.8333  1815.242  (P)

         |                                           -918.6465  1713.917 (BC)

-----------------------------------------------------------------------------

                              N = normal, P = percentile, BC = bias-corrected

ATT estimation with Nearest Neighbor Matching method

(random draw version)
```

Bootstrapped standard errors

```
---------------------------------------------------------

n. treat.   n. contr.         ATT   Std. Err.           t

---------------------------------------------------------

      120          49    1062.667     519.959       2.044

---------------------------------------------------------

Note: the numbers of treated and controls refer to actual

nearest neighbour matches
```

. xi: atts teffcrop_income participation, pscore(ppscore) blockid(myblockii) comsup bootstrap reps(50)

```
ATT estimation with the Stratification method
```

Bootstrapping of standard errors

```
command: atts teffcrop_income participation, pscore(ppscore) blockid(myblockii) comsup

statistic:   r(atts)(obs=300)

Bootstrap statistics

Variable |   Reps   Observed       Bias   Std. Err.   [95% Conf. Interval]
---------+-------------------------------------------------------------------
     bs1 |     50   1077.854  -52.18086   389.0233    296.0826  1859.626  (N)
         |                                            41.39476  1575.417  (P)
         |                                            41.39476  1577.936 (BC)
-----------------------------------------------------------------------------
                              N = normal, P = percentile, BC = bias-corrected

ATT estimation with the Stratification method

Bootstrapped standard errors

---------------------------------------------------------

n. treat.   n. contr.         ATT   Std. Err.           t

---------------------------------------------------------

      120         144    1077.854     389.023       2.771

---------------------------------------------------------
```

. xi: attk teffcrop_income i.participation, pscore(ppscore) logit index comsup bootstrap reps(50)

```
i.participation   _Iparticipa_0-1     (naturally coded; _Iparticipa_0 omitted)

 The program is searching for matches of each treated unit.

 This operation may take a while.
```

Bootstrapping of standard errors

```
command: attk teffcrop_income _Iparticipa_1, pscore(ppscore) comsup logit index
bwidth(.06) statistic:   r(attk) (obs=300)

Bootstrap statistics

Variable |   Reps   Observed       Bias   Std. Err.   [95% Conf. Interval]
```

```
---------+-------------------------------------------------------------
     bs1 |     50   1004.172  -87.78065   366.0902     268.486  1739.857  (N)
         |                                            168.8491  1467.939  (P)
         |                                            -151.289  1467.939 (BC)
-----------------------------------------------------------------------
                              N = normal, P = percentile, BC = bias-corrected
```

ATT estimation with the Kernel Matching method

Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
120	144	1004.172	366.090	2.743

. xi: attr teffcrop_income i.participation, pscore(ppscore) logit index comsup bootstrap reps(50)i.participation _Iparticipa_0-1 (naturally coded; _Iparticipa_0 omitted)

The program is searching for matches of treated units within radius.

This operation may take a while.

ATT estimation with the Radius Matching method

Bootstrapping of standard errors

command: attr teffcrop_income _Iparticipa_1 , pscore(ppscore) logit index comsup radius(.1)

statistic: r(attr) (obs=300)

Bootstrap statistics

```
Variable |   Reps   Observed       Bias   Std. Err.   [95% Conf. Interval]
---------+-------------------------------------------------------------
     bs1 |     50   1959.602  -236.8607   350.7516    1254.741  2664.464  (N)
         |                                              1119.2   2281.56  (P)
         |                                            1423.916  2460.541 (BC)
-----------------------------------------------------------------------
                              N = normal, P = percentile, BC = bias-corrected
```

ATT estimation with the Radius Matching method

Bootstrapped standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
120	144	1959.602	350.752	5.587

Note: the numbers of treated and controls refer to actual matches within radius

Annex table 3 Base line ATT and Simulated ATT

THIS IS THE BASELINE ATT ESTIMATION (WITH NO SIMULATED CONFOUNDER).
The program is searching the nearest neighbor of each treated unit.
This operation may take a while.

ATT estimation with Nearest Neighbor matching method (random draw version)

Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
120	49	1062.667	590.721	1.799

Note: the numbers of treated and controls refer to actual nearest neighbour matches

*** THIS IS THE SIMULATED ATT ESTIMATION (WITH THE CONFOUNDER U).

The probability of having U=1 if T=1 and Y=1 (p11) is equal to: 0.90
The probability of having U=1 if T=1 and Y=0 (p10) is equal to: 0.85
The probability of having U=1 if T=0 and Y=1 (p01) is equal to: 0.75
The probability of having U=1 if T=0 and Y=0 (p00) is equal to: 0.60

The probability of having U=1 if T=1 (p1.) is equal to: 0.89
The probability of having U=1 if T=0 (p0.) is equal to: 0.65

The program is iterating the ATT estimation with simulated confounder.
You have chosen to perform 50 iterations. This step may take a while.

ATT estimation with simulated confounder General multiple-imputation standard errors

ATT	Std. Err.	Out. Eff.	Sel. Eff.
1033.184	671.776	113.803	4.225

Note: Both the outcome and the selection effect are odds ratios from logit estimations.

*** THIS IS THE BASELINE ATT ESTIMATION (WITH NO SIMULATED CONFOUNDER).

The program is searching for matches of each treated unit.
This operation may take a while.

ATT estimation with the Kernel Matching method

n. treat.	n. contr.	ATT	Std. Err.	t
120	144	1004.172	.	.

Note: Analytical standard errors cannot be computed. Use
The bootstrap option to get bootstrapped standard errors.
*** THIS IS THE SIMULATED ATT ESTIMATION (WITH THE CONFOUNDER U).

The probability of having U=1 if T=1 and Y=1 (p11) is equal to: 0.95
The probability of having U=1 if T=1 and Y=0 (p10) is equal to: 0.80
The probability of having U=1 if T=0 and Y=1 (p01) is equal to: 0.75
The probability of having U=1 if T=0 and Y=0 (p00) is equal to: 0.65

The probability of having U=1 if T=1 (p1.) is equal to: 0.92
The probability of having U=1 if T=0 (p0.) is equal to: 0.68
The program is iterating the ATT estimation with simulated confounder.
You have chosen to perform 50 iterations. This step may take a while.

ATT estimation with simulated confounder
General multiple-imputation standard errors

ATT	Std. Err.	Out. Eff.	Sel. Eff.
1003.450	.	12.229	5.009

*** THIS IS THE BASELINE ATT ESTIMATION (WITH NO SIMULATED CONFOUNDER).

The program is searching for matches of treated units within radius.

This operation may take a while.

ATT estimation with the Radius Matching method Analytical standard errors

n. treat.	n. contr.	ATT	Std. Err.	t
120	144	1959.602	273.208	7.173

Note: the numbers of treated and controls refer to actual matches within radius

*** THIS IS THE SIMULATED ATT ESTIMATION (WITH THE CONFOUNDER U).

The probability of having U=1 if T=1 and Y=1 (p11) is equal to: 0.95

The probability of having U=1 if T=1 and Y=0 (p10) is equal to: 0.95

The probability of having U=1 if T=0 and Y=1 (p01) is equal to: 0.85

The probability of having U=1 if T=0 and Y=0 (p00) is equal to: 0.75

The probability of having U=1 if T=1 (p1.) is equal to: 0.95

The probability of having U=1 if T=0 (p0.) is equal to: 0.78

The program is iterating the ATT estimation with simulated confounder.

You have chosen to perform 50 iterations. This step may take a while.

ATT estimation with simulated confounder

General multiple-imputation standard errors

ATT	Std. Err.	Out. Eff.	Sel. Eff.
1869.640	290.502	5.509	6.846

Annex table 4 Econometric result of using Heckman two stage selection model

Heckman selection model -- two-step estimates
(Regression model with sample selection)

Number of obs = 300
Censored obs = 180
Uncensored obs = 120
Wald chi2(11) = 105.55
Prob > chi2 = 0.0000

Teff crop income	Coef.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
hh_sex	299.0005	423.0162	0.71	0.480	-530.0961	1128.097
hh_age	-17.96938	17.68833	-1.02	0.310	-52.63787	16.6991
hh_education	159.1491	92.45776	1.72	0.085 *	-22.06475	340.363
hh_familysize	-102.2555	90.22131	-1.13	0.257	-279.086	74.575
cultivatedlandsize	1382.068	146.0049	9.47	0.000 ***	1095.903	1668.232
tlu	744.5317	235.2163	3.17	0.002 ***	283.5162	1205.547
extensionservice	1538.27	1501.411	1.02	0.306	-1404.442	4480.981
accesstocredit	265.1797	416.4592	0.64	0.524	-551.0654	1081.425
useoffertilizer	193.8648	402.4328	-0.48	0.630	-982.6186	594.889
irrigation_access	84.18839	319.3941	0.26	0.792	-541.8126	710.1894
availabilityoflabor	471.0404	361.7833	1.30	0.193	-238.0417	1180.123
cons	-4792.292	3052.001	-1.57	0.116	-10774.1	1189.52
participation						
hh_sex	-.0186556	.2445041	-0.08	0.939	-.4978748	.4605637
hh_age	-.0017655	.0092767	-0.19	0.849	-.0199475	.0164165
hh_education	.1071928	.0495488	2.16	0.031 **	.010079	.2043066
hh_familysize	-.0174097	.0525196	-0.33	0.740	-.1203463	.0855269
cultivatedlandsize	.1550555	.0687661	2.25	0.024 **	.0202764	.2898346
tlu	.4933309	.0764488	6.45	0.000 ***	.343494	.6431679
extensionservice	1.143373	.5614817	2.04	0.042 **	.0428894	2.243857
accesstocredit	.0673359	.2288972	0.29	0.769	-.3812943	.5159661
useoffertilizer	.0025805	.2376831	0.01	0.991	-.4632698	.4684308
irrigation_access	-.0645564	.1838087	-0.35	0.725	-.4248148	.295702
availabilityoflabor	.3974544	.1962622	2.03	0.043 **	.0127875	.7821213
socialcapital	.2041109	.1815162	1.12	0.261	-.1516542	.559876
ocialnetwork	.0064837	.1950906	0.03	0.973	-.375887	.3888543
ftc_near	.3713775	.1800966	2.06	0.039**	.0183947	.7243604
cons	-3.6859	.8529781	-4.32	0.000 ***	-5.357707	-2.014094
mills | lambda	1765.957	889.5638	1.99	0.047 **	22.44392	3509.47
Rho	0.95866					
Sigma	1842.1103					

Note * , ** and *** shows significance at 10%, 5% and 1& probability level.

Annex table 5: OLS estimate result

```
reg teffcrop_income hh_sex hh_age hh_education hh_familysize cultivatedlandsize tlu
extensionservice accesstocredit useoffertilizer participation irrigation_access
availabilityoflabor socialcapital socialnetwork ftc_near

      Source |       SS       df       MS              Number of obs =      300
-------------+------------------------------           F( 15,   284) =    76.12
       Model |  1.3665e+09    15  91103125.6           Prob > F      =   0.0000
    Residual |   339900793   284  1196833.78           R-squared     =   0.8008
-------------+------------------------------           Adj R-squared =   0.7903
       Total |  1.7064e+09   299  5707182.87           Root MSE      =     1094

------------------------------------------------------------------------------------
    teffcrop_income |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
--------------------+---------------------------------------------------------------
             hh_sex |  -51.84371   180.4784    -0.29   0.774    -407.0888    303.4014
             hh_age |  -18.10762   6.785579    -2.67   0.008    -31.46403   -4.751216
       hh_education |   51.10743   37.43556     1.37   0.173    -22.57893    124.7938
      hh_familysize |  -32.50469   38.94595    -0.83   0.405     -109.164    44.15465
 cultivatedlandsize |   1189.456    52.6099    22.61   0.000     1085.901    1293.011
                tlu |   187.6937   52.06109     3.61   0.000     85.21917    290.1683
   extensionservice |   130.0429   272.6803     0.48   0.634     -406.688    666.7738
     accesstocredit |   61.63797    166.583     0.37   0.712     -266.256     389.532
    useoffertilizer |  -295.0457   170.5833    -1.73   0.085    -630.8138    40.72238
      Participation |   851.3481   155.6243     5.47   0.000     545.0247    1157.671
  irrigation_access |  -59.84244   137.0844    -0.44   0.663    -329.6727    209.9879
availabilityoflabor |   279.0356   146.3796     1.91   0.058    -9.090988    567.1622
      socialcapital |  -28.96483   133.7076    -0.22   0.829    -292.1485    234.2188
      socialnetwork |  -203.3876    141.299    -1.44   0.151    -481.5139    74.73863
           ftc_near |  -71.38857   134.2655    -0.53   0.595    -335.6704    192.8933
              _cons |   339.2458   512.8005     0.66   0.509    -670.1261    1348.618
------------------------------------------------------------------------------------
```

Annex table 6: multicolliniarity test

```
vif

    Variable |       VIF       1/VIF

-------------+----------------------

hh_education |      1.69    0.590408

      hh_age |      1.43    0.698491

cultivated~e |      1.25    0.801486

         tlu |      1.12    0.890457

hh_familys~e |      1.09    0.920453

-------------+----------------------

    Mean VIF |      1.32
```

. corr teffcrop_income hh_sex extensionservice accesstocredit useoffertilizer participation irrigation_access availabilityoflabor socialcapital s ocialnetwork ftc_near (obs=300)

```
             | teffcr~e hh_sex extens~e access~t useoff~r partic~n irriga~s availa~r social~l social~k ftc_near

-------------+------------------------------------------------------------------------------------

teffcrop_i~e |   1.0000

      hh_sex |   0.1160   1.0000

extensions~e |   0.2137  -0.0015   1.0000

accesstocr~t |   0.1710   0.0546   0.0753   1.0000

useofferti~r |   0.0224  -0.0353   0.0590   0.1180   1.0000

participat~n |   0.5030   0.0408   0.1844   0.1021   0.0214   1.0000

irrigation~s |  -0.0451  -0.0062   0.0060  -0.0782   0.0058  -0.0174   1.0000

availabili~r |   0.2814  -0.0015   0.0803   0.1273   0.1450   0.1573   0.0134   1.0000

socialcapi~l |   0.0577   0.0274   0.0912   0.0271   0.0257   0.0388  -0.0455  -0.0694   1.0000

socialnetw~k |   0.0894  -0.0964   0.1355   0.1237  -0.0680   0.0577  -0.0352   0.0486   0.1344  1.0000

    ftc_near |   0.0028  -0.0139  -0.0054  -0.0702  -0.0428   0.0873   0.1082  -0.2158   0.0616   0.1182   1.0000
```

Annex table 7: Conversion Factors to Estimate TLU

Livestock Category	TLU	Livestock Category	TLU
Ox	1.00	Horse	1.10
Cow	1.00	Camel	1.25
Heifer	0.75	Sheep (adult)	0.13
Bull	1.00	Sheep (young)	0.06
Horse	0.75	Goat (adult)	0.13
Calf	0.25	Goat (young)	0.06
Donkey (adult)	0.70	Chicken	0.013
Donkey (young)	0.35		

Source: Storck, *et at.*, (1991)