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THE IMPACT OF ADOPTING WHEAT ROW PLANTING TECHNOLOGYON YIELD: THE CASE OF SMALLHOLDER FARMERS IN CHEHAWOREDA, GURAGE ZONE, SNNPR, ETHIOPIA

MSc. THESIS

BY

FREWEYIN DEGEMU BESIR

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WOLKITE, ETHIOPIATHE

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MSc. T H E S I S

FREWEYIN DEGEMU BESIR

MAIN ADVISOR: ABDULAZIZ A. MOSA (PhD)

CO-ADVISOR: LEMMA SHALLO (MSc)

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WOLKITE, ETHIOPIA

DECLARATION

I hereby declare that the thesis entitled '**the impact of adopting wheat row planting technology on yield: the case of cheha woreda, gurage zone'** is result of my own effort. I have prepared the thesis independently with the guidance and support of the research advisors. The study has not been submitted to the award of any degree in any college. It is submitted for the college in partial fulfillment of the requirements for the Degree of Master of Science in Economics.

Name of the student: Fraweyin Degemu Besir

Signature: _____

Date of submission: _____

ADVISORS'APPROVAL SHEET

As thesis advisor, we hereby certify that we have read and evaluated this thesis Prepared under our guidance by **FREWOYIN DEGEMU BESIR** entitled **THE IMPACT OF ADOPTING WHEAT ROW PLANTING TECHNOLOGY ON YIELD: THE CASE OF SMALL HOLDER FARMERS IN CHEHA WOREDA, GURAGE ZONE**. We recommend that it be submitted as fulfilling the research requirement.

Main Adviser's Name	**Date**	**Signature**
_____	_____	_____
Co- Adviser's Name	**Date**	**Signature**
_____	_____	_____

EXAMINERS' APPROVAL SHEET

As Members of the Examining Board of the Final MSc Thesis Defense, we certify that we have read and evaluated the thesis prepared by Fraweyin Degemu and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Economics.

Chair Person	Signature	Date
_____	_____	_____
Interna Examiner	Signature	Date
_____	_____	_____
External Examiner	Signature	Date
_____	_____	_____

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LIST OF ABBREVIATIONS/ACRONOMYS

ATA	Agricultural Transformation Agency
BOARD	Bureau of Agriculture and Rural Development
BOFED	Bureau of Finance and Economic Development
GZARDO	Gurage Zone Agriculture and Rural Development Office
FAO	Food and Agricultural Organization
FTC	Farmer Training Center
ChWARDO	Cheha Woreda Agriculture and Rural Development Office
GDP	Gross Domestic Product
GOE	Government of Ethiopia
CSA	Central Statistical Agency
NBE	National Bank of Ethiopia
PSM	Propensity Score Matching
SSA	Sub Sahara Africa
TLU	Tropical Livestock Unit

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 wheat crop on yield in cheha wereda Gurage zone. Both descriptive and econometric data analysis techniques were applied. The analysis was based on primary household level cross sectional data collected from 324 randomly selected rural households of which 130 user of row planting and 194 row planting non-user and secondary data were employed. Both descriptive and econometric data analysis techniques applied in this study. The result of the study showed most of the household's characteristics are statistically significant with user and non-user households. Variables like household age; household size; household income before sowing in birr; income after sowing in birr; total wheat yield and income after in quintal shows statistically mean difference between user and nonuser households. The study used four matching methods; these methods are; nearest neighborhood, radius, kernel and stratification matching methods to identify the impact of row planting technology on households' yield production. Practical training should be provided for the farmers and there should be easy referral systems where user households can go when they face difficulties, maintenance issues and spare parts.

Keywords: wheat row planting, propensity score matching, Probit Model, adoption and impact.

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

Wheat is one of the major food crops in Ethiopia. It is the second important cereal crop with annual yield of about 3.43 million tons cultivated on area of 1.63 million hectares (CSA, 2013). According to the CSA data, wheat occupied about 17% of the total cereal area with average national yield of 21.10q/ha. This is the lowest yield compared to the world average yield of 40 q/ha (FAO, 2009).

Today in the world most developing countries faces two key challenges such as ensuring both food security and poverty alleviation. The increase in crop production is important for improving the welfare of small-scale farmers in these countries. With rapidly growing population rate and limited cultivable farm land, in the agriculture sector technological involvement and technical efficiency seems to be the only possible option low income countries to provide food for the increasing population and generate employment (Hashmi et al., 2015).

In developing world, agricultural sector has a lion share not only in poverty mitigation or to ensure food security but also contributes GDP, employment and income generation particularly in Sub-Saharan African (SSA) countries (Bilaliib et al.,2017, Vandercasteelen et al.,2018). Poverty alleviation and economic growth can usually be attained by agricultural growth that creates spillover effects to the remaining sectors.

Agriculture plays a vital role in the Ethiopian economic development (Aynalem et al., 2018; Yadeta and Temesgen, 2018). Although owing to natural and manmade causes made the nation has not properly benefited from its abundant natural resources and good agricultural development that enable its people pullout of poverty (FAO, 2017)

In Ethiopia, the major challenges facing agriculture are low productivity, low use of improved farm inputs, and dependency on traditional farming and rainfall. As a result, food insecurity and poverty are prevalent in the country. Wheat is one of the major food crops with low productivity. As Menale et al (2018) stated the low productivity subsistence is characteristic of most traditional agriculture because of traditional tools and limited improved technology and small areas intensively cultivated subject to diminishing returns and increased labor inputs.

The low yield has made the country unable to meet the high demand and the country remains net importer despite its good potential for wheat production (Rashid, 2010). Increasing yield and meeting the high demand has become the main concern of government's agricultural policy and extension activities.

In Cheha Woreda the production of crops depends mainly on the rainfall and several hectares are grown annually. However, productivity is as such not much satisfactory. To improve this lowest productivity, among all others, the good farming practice is the most important thing especially to implement the in line planting technology on smallholder farmers.

On the contrary, even if farmers were convinced to practice row planting, absence of appropriate technology was the main bottleneck for its development (Tamrat et al., 2017).Of course; there are several techniques to boost the wheat production and its productivity. Among which in line technology adoption is one of the major technique for its yield variation. In reality, the usual broadcast sowing technique has been identified as the major constraints to rise wheat yields. Therefore, today more attention has to be given for the alternative sowing method that focuses on the row planting technology with its reduced seeding rates for more favorable till ring and branching out the wheat plants.

Even if this technology has such more importance to increase the productivity on wheat yield, only a few farmers almost estimated to 36% used it whereas the rest 64% used the traditional broadcasting sowing method in Cheha Woreda (ChWOARD, 2019). This proportion is even less than the national level. Hence, in the study area, this technology might be affected by different factors that may hinder its adoption and the yield among smallholder farmers.

1.2 Statement of the Problem

Wheat is one of the major food crops in Ethiopia. It is the second important cereal crop with annual yield of about 3.43 million tons cultivated on area of 1.63 million hectares (CSA, 2013). According to the CSA data, wheat occupied about 17% of the total cereal area with average national yield of 21.10q/ha. This is the lowest yield compared to the world average yield of 40 q/ha (FAO, 2009). The national average yield levels are low because highly characterized by rain fed, subsistence oriented, broadcast farming system, low adoption of row planting technology, poor agricultural performance, income variability and high population growth.

To meet up the increasing demand for wheat by the rapidly growing population in the country, it is very essential to increase its production and productivity in the country side. The government of Ethiopia has been giving top priority to agricultural technology and utilizing core resources to extension and the intervention of high yielding variety (CSA, 2017).

According to Ejegayehu(2016), agricultural productivity can be improved with improvements in farmer use of improved production technologies like row planting even within the existing resources. One of the technologies in crop production introduced in the recent years is row planting. Compared to the conventional broadcasting, the row seeding system gives better yield as it allows better weeding and for better branching out and nutrient uptake of the plants and lessen competition between seedlings.

Several adoption study findings have shown that the adoption of new row planting agricultural technologycouldleadtosignificantlyenhanceinagriculturalproductionthat encourage the transition from low production subsistence to a high production agro-industrial economy. For instance, (Alemu T. , 2014) impact of wheat row planting on yield of smallholders in selected highland and lowland areas of Ethiopia, Negese, Jemal and Endeg (2017) identified the main determinants of wheat row planting technology adoption in Duna Woreda, Hadiya Zone, and SNNPR .The results were identified as: age, education, and family size of household head, cultivated land size, livestock holding, and use of extension and credit services were significantly affect behavior of farmers for adopting wheat row planting. In spite of the government‘s efforts to address the question of low productivity, the row planting still remains difficult to be practiced by the farmers in this area (SNNPR).

In Cheha wereda, In spite of the government‘s efforts to address the question of low productivity, the row planting still remains difficult to be practiced by the farmers (CHWARDO, 2021).

Only a few empirical studies have been done so far, regarding to the new wheat crop row planting technology adoption in the Ethiopian context. However, most of these studies conducted were limited to specific area and have inadequate information on wheat crop row planting technology adoption and its impact on yield in Gurage Zone in general and Cheha woreda in particular. Not only this but also, these and some other related studies on this new technology adoption did not touched some important variables like: farmer’s participation in agricultural training, field day demonstration, off farm participation, and access to media (information) as important. In addition to the binary logit model, to address the observable characteristics of the explanatory variables, PSM, which is the popular technique to assess the impact of any intervention and used to determine the probability of participation in different program is appropriate to apply especially by incorporating the sensitivity analysis that supports the robustness of estimated results of the intervention.

In the area where this study is conducted, the farmers did not dare to adopt the method of planting wheat in a row due to the problem of labor, time and money. Since there is no previous study on this topic in the district, the farmer has not been confirmed by the research on how much production can be increased by planting wheat in rows. Considering the labor time and money it will take, most farmers do not dare to sow in rows, so this study solves this problem.

Therefore, this study intended to assess the impact of the row planting on yield, to assess the opinion of farmers about the new agricultural technology and factors that affect the adoption of new practice in this wereda and also fills research gaps by conducting an empirical assessment on adoption wheat row planting technology and its impact on yield.

1.3 Objective of the study

1.3.1 General objective

The general objective of this research is to investigate the impact of adopting wheat row planting technology on yield the case of smallholder farmer's.

1.3.2 Specific Objectives

- To identify factors that influence smallholder farmer's decision to use row planting technology in the study area
- To evaluate the impact of wheat row planting technology adoption on its yield in the study area.

1.4 Research questions

1. What are the potential factors that influence the adoption of row-planting technology by smallholder farmers?
2. To What extent wheat row-planting technology impacted its yield?

1.5 Significance of the study

This study will provide important information on factors that determine wheat row-planting technology adoption and its impact on wheat productivity over smallholder farmers as it is a newly introduced agricultural technology on wheat producing smallholders. It will also provide the insight on the effect of sowing in line on agricultural productivity for agricultural office and other concerned body. Furthermore, this research will be to serve as abridge for other studies in the future on same and other related issue and may address policy implication to foster economic growth in Gurage Zone, Southern Ethiopia. Therefore, this study may serve as a source of additional information which may be of significant use to policy makers and planners of Cheha woreda as well as the region during the implementation of row planting agricultural technology adoption.

1.6 Scope of the study

This study specifically focuses on row planting of wheat technology adoption and its impact on yield among small household farmers in the research area. Since it is not possible to cover the whole Gurage Zone 16 rural districts with the available time and resources, the research is limited to the specific study area Cheha woreda, Southern Ethiopia which is the most wheat production potential woreda among others in Gurage Zone. The study considers farmers who are practicing in line planting of wheat 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 the reason why not to adopt by non- users of the technology will be addressed.

1.7. Limitation of the study

A limitation of this study is the complexity of topographic data collection of the study area. In addition to this, the difficulty of obtaining adequate information from the district and secondary information.

1.8. Organization of the Study

The paper will be structured as follows in to five chapters. The first chapter states the introduction, which comprises the background information, problem statement, objectives, scope and significance. Chapter two presents literature review which includes concepts on practicing wheat row planting technology adoption & its impact on wheat yield. Chapter three introduces the methodology, which includes description of the project and study area, source and methods of data collection and analysis as well. Chapter four brings the results and discussion of the research outcomes and finally chapter five comes up with summary, conclusion and recommendations.

CHAPTER TWO

2 REVIEW OF RELATED LITERATURE

2.1 Theoretical Literature Review

2.1.1 Definition of terms and concepts

The adoption is a decision-making process, in which a person goes through a number of mental stages before making a last 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). Technology adoption refers to a decision to make full application of an innovation as the best course of action (Rogers, 2003). Technological adoption in agriculture comprises of introduction of high yielding variety of seeds, fertilizers, plant protection measures and sowing system. These changes in agricultural sector enhance the productivity per unit of land and bring about rapid increase in production. Technology is assumed to mean a new, scientifically derived, input supplied or introduced to farmers by organizations with deep technical expertise (Albert and Peter, 2018). Majority of the agricultural technology include irrigation, fertilizer use, high yield variety seeds and row plantation that focused on green revolution technologies (Aynalem *et al.,* 2018). The two common approaches of technology adoption of agricultural technology include whole package adoption advocated by technical scientist and stepwise or sequential adoption recommended by farming system and participatory research groups (Bultossa, 2018). Generally, technological adoption refers the utilization of new technological input and enhancing agricultural productivity.

2.1.2. Overview of row planting

Planting with space' involves the growing of plants on a small farm land with sufficient space between each of the plants so that they can develop their roots and shoots more fully (Negese *et al.,* 2017). As emphasized by ((ATA), Agricultural Cooperative Sector Development Strategy, 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. According to Yalemwork (2018) there is a traditional type of planting with space.

That is in most rural areas farmers lightly plough and lift the plants out from the densely growing areas and re-plant them in the gaps. Scaling up of the adoption of yield-increasing technological innovations could therefore potentially have large benefits for boosting agricultural productivity in SSA (Hassen, 2016; Albert and Peter, 2018). As Ejegayehu (2016) stated an important determinant of the success of new agricultural technologies is not only the superiority of the technology itself but also the transmission of information about the new technology to farmers.

2.1.3. Wheat row planting in the Cheha district

Sowing system of crop production had significant effect on crop productivity. The highest crop yield was obtained from row planting system and the lowest one was from conventional method of sowing system. The highest crop productivity in line sowing system was due to maximum efficient use of planting system and give highest productivity. Row planting used for proper allocation of resource like fertilize and easily control the amount of weed in wheat production. Row planting with reduced seeding rate and proper implementation of agronomic best practices increases wheat yield. According to Cheha district office of Agriculture (2020) report; wheat row planting technology introduced in 2013 G.C. to the district and it was first applied on selected Farmer Training Center (FTCs) (row planting and transplanting of seedlings). Afterward, the district agriculture office continued to scale up the adoption of the technology to the wheat producing belts. Even though such interventions, adoption of row planting technology in Gurage zone specifically in the study district is still low and the dominant sowing system of the district is broadcast sowing system which is also limited to Meher season only. However, continued investments by the Government have helped farmers to increase their crop production and productivity by adopting yield-enhancing inputs so that farmers can benefit from economies of scale (ATA, 2017).

2.1.4. Factors Affecting Adoption of Agricultural Technology

The factors affecting technology adoption in agricultural technologies can classified in farmer characteristics, farm structure, institutional characteristics and managerial structure (Albert and Peter, 2018). Access to credit service, extension visit and source of information could affect the adoption of new innovation by the farmers. The need to provide credit services to the farmers to empower them so as to acquire inputs which will enhance their adoption of new technologies (Adunea and Fekadu; 2019). Farmers' participation in trainings and visits has made them to achieve relevant and timely information about agricultural production could motivate them to adopt agricultural technology (ATA, 2017; Aynalem *et al.,* 2018).

Technology actually plays a crucial in agricultural modernization, but the process cannot be understood solely in terms of technology (Gashaw *et al.,* 2018). The interactions of technology with a number of social and economic factors have to be taken into account. The adoption of recommended management practices depended on the cost of the practice (Negese *et al.,* 2017).

The rate of adoption of a new technology is subject to its profitability and the degree of risk and uncertainty related with it and it is highly influenced by the capital requirement and agricultural policies, and the socio-economic characteristics of farmers (Hassen, 2016; Hnana *et al.,* 2017).

According to Tafese (2016), a farmer's decisions about whether and how to adopt new technology are conditioned by the dynamic interaction between characteristics of the technology and the array of conditions and circumstances. Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it.

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 association with environmental conditions (Tafese, 2016). Therefore, disseminating improved agricultural technologies without consultation of farmers most probably ends with failure (Adunea and Fekadu, 2019).

Technology adoption among farmers is higher when extension services are made available. Through extension services, farmers get to know the benefits of new technology through extension agents. Extension agent acts as a link between the innovators (Researchers) of the technology and adoptors

of that technology (Aynalem *et al.*, 2018). Institutional variables play important role in the everyday operations of farm businesses.

Access to extension services significantly promotes rice yield for adopters and non-adopters. However, the impact of extension on adopters is higher than that of non-adopters (Bilaliib *et al*., 2018). Agricultural extension is the system of learning and building human capital of farmers through the provision of information and demonstrations, exposing farmers to technologies which can increase agricultural productivity and, in turn, raise income and welfare of the farmers (Adunea and Fekadu, 2019).

According to (Janvry *et al*., 2016) 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 'characteristics (sex, age, and formal education) and (3) institutional support system available for inputs. The row planting is labor intensive practice and it needs high labor for seeding on the farm.

2.2. Empirical Literature Review

A number of empirical studies have been conducted on the determinant factors that affect agricultural technology adoption at household level. These have been undertaken by different researchers and institutions on the adoption of agricultural new technologies. Of course, the studies were mainly conducted around major cereals crop and mostly commonly explained variables.

In most studies, farmers' decision to adopt a technology has determined by demographic and personal, socio economic, psychological and institutional factors. Thus, in this section the emphasis given to review of empirical literatures related to farm and farmers' characteristics, institutional factors and farmers' perception towards attributes of new row planting technologies.

Therefore, the researcher reviewed different studies that mainly focus on : farmers' socio economic characteristics such as sex, age, educational level ;economic factors like household labor, tropical livestock ownership ; institutional factors like extension service, participation in agricultural training, off farm participation and technological factors such as application of inorganic fertilizer that were important factors influencing farmers' decisions to adopt new technologies (Doss,2003).

Berihun et al., (2014), using logit model found that female headed households had (For a variety of reasons, she is the head of the household without a husband) negative relationship with the adoption of wheat row planting technology. This means female headed households have smaller probabilities of being adopter than male house hold head Southern Tigrai State of Ethiopia. However; the study done by Donkor *etal*., (2016); the variable sex has significant negative effect on adoption of rice row-planting. Meaning that, male farmers are less likely to plant their seeds in rows as compared to females. This is not surprising since in the Northern Ghana, planting of seeds is regarded as female activity. Because, crop row planting may vary from place to place or region to region regarding with female headed households and their counterpart male.

Besides, as the study conducted by Berihun et al., (2014) shows family size and adoption status of the wheat row planting technology was robustly and positively related. This could be due to the labor intensive nature of the technology. In addition, it was found that household education status significantly affects the adoption of wheat row planting technology. This implies that better educated household heads are in a position to understand and interpret what ever technology easily and implement own farms .Oxen ownership affected significantly and related positively with the adoption of wheat row planting technology. The ownership of more oxen assists the households in combating the shortfall of labor requirements from land preparation planting and sowing. This in turn helps house holding the cash requirements for seeds, fertilizers and other inputs through selling them at needy seasons. On the other hand, it could also be source of cash to be paid as a wage for additional daily labor.

The study conducted by Kafale and Hassen(2012), under taken in Bara district of Nepal using Maximum Likelihood Estimation of logit model and concluded that access to off-farm income, farm size, membership of organization , farming experience availability of credit were not important factors of adoption of improved technology. Whereas education, house hold size, access to extension, cattle ownership, age were found positively and significantly influenced new technology adoption in the study area.

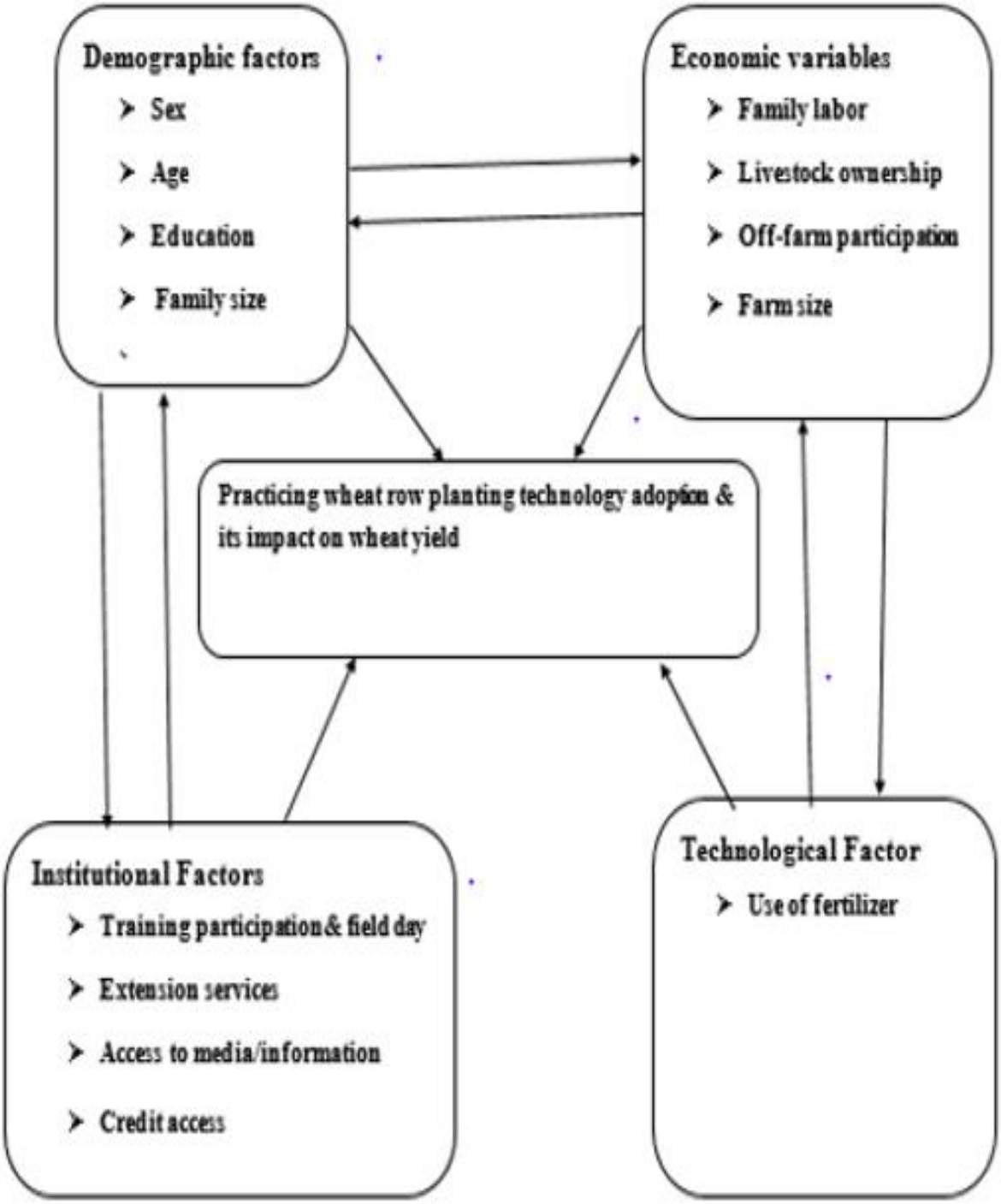
Merga and Urgessa (2014) conducted study on determinant and impact of wheat technology adoption in West Wollega: the case of Gulliso district by using logistic regression showed that household heads 'education level, farm size, credit accessibility perception of farmers about cost of the inputs and off-farm income positively and significantly affected farm households' adoption decision, while family size affected their decision negatively and significantly. The result of the propensity score matching estimation revealed that the average income and consumption expenditure of adopters are greater than that of non-adopters.

2.3. Conceptual Framework and Theoretical background

As it was emphasized by Bilaliib et al.,(2017), Agricultural technology adoption rates were vary between different group of farmers as a result of differences in access to resources (land, labor, and capital) & information and differences in farmers' perceptions of risks and profits associated with new technology. Also, in most developing countries, like Ethiopia, farmers 'adoption behavior can be influenced by a complex set of socio-economic, demographic, technical, institutional and physical factors. Hence, direction and degree of impact of adoption determinants are not uniform as the impact varies depending on type of technology and the conditions of areas where the technology to be introduced.

In general, both the background information and the review of literature on wheat production and productivity problems provide the main key factors, concepts and or variables that need to be included in this particular study. These interlinked key factors, concepts and or variables that directly or indirectly influence on one another include: the impact of sowing in line of wheat according to farmers' personal characteristics, accessibilities to different services like extension, and other institutional as well as technological factors that have their own impact on wheat yield.

Figure 2.3.1: Conceptual Framework of the Study



Source: Author's compilations

CHAPTER THREE
3 RESEARCH METHODS AND MATERIALS

This chapter describes the overall methodology of the research. It generally consists three major sections. In the first section, the proposed area is described briefly. The second section describes about information on the sources and methods of data collection while the last part explains data analysis methods.

3.1. Description of the study area

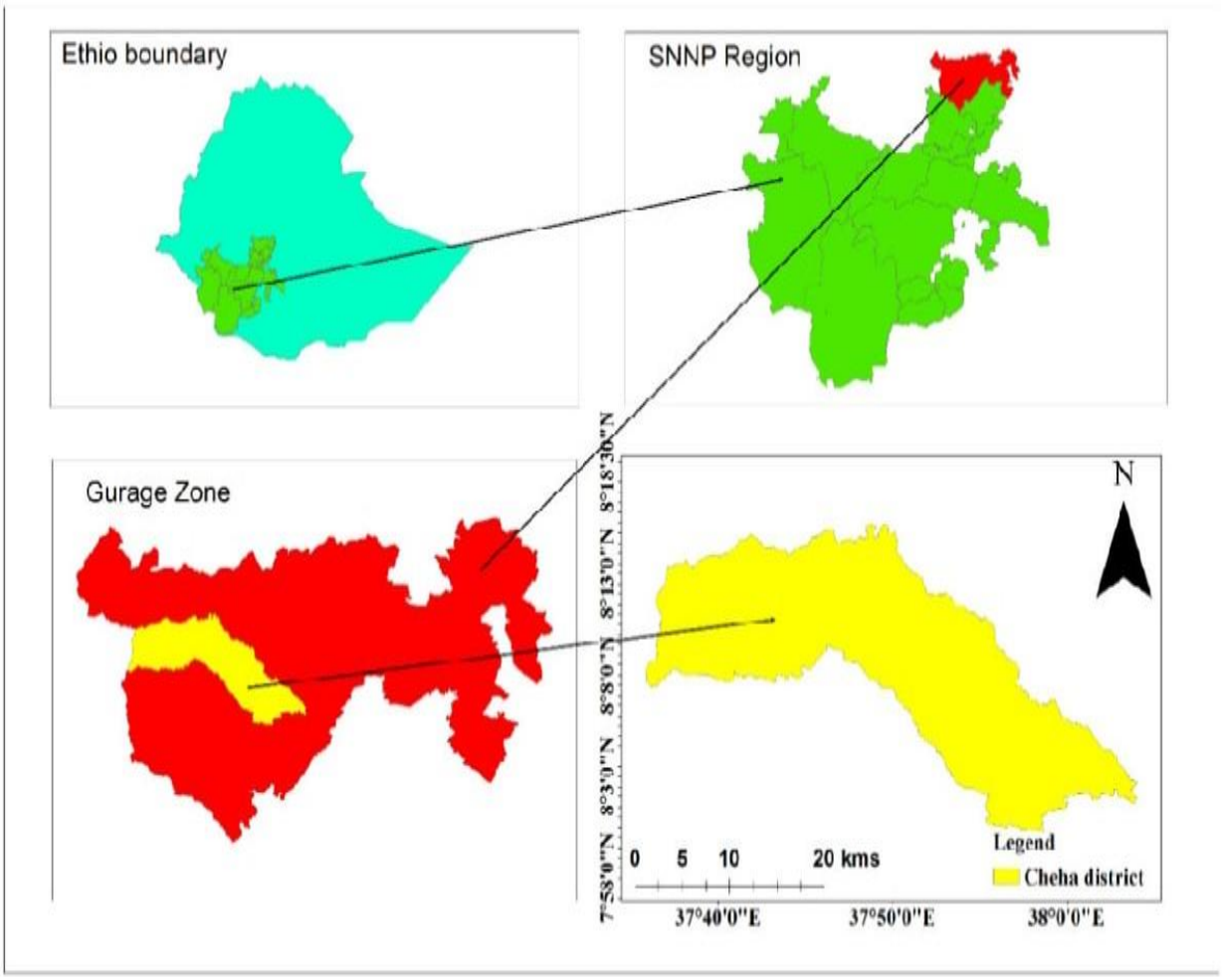
Gurage Zone is one of ten zones in SNNRP region and an area of great geographical diversity. Gurage zone lies in between 7° 40' to 8° 30' north latitudes and 37° 30' to 38° 40' east longitudes. It also has great physical, altitudinal and climatic variations. A large part of the area composed of strongly dissected hilly to mountainous (40%) developed on granite rocks. The rest 60% of the land is flat and convenient for farming. The zone shares boundaries with on the southeast by Hadiya and Yem special woreda, on the west, north and east by the Oromia Region, and on the southeast by Silt'e. Since the 1999/2007 population and housing census, the population of Gurage Zone is estimated to grow at an average rate of 4.2% perineum. Based on this estimation the zonal population was 1,947,654 in 2020/21. The Zone has recently 16 rural Woreda and five town administration. Cheha Woreda is one of among 16 rural Woreda having total of 38 Kebeles and it is considered as one of the Zone‘s district with high potential for wheat production. From those Kebeles 9% Derek Weynadega (low land), 71% Weynadega(mid- high land) and 20% Dega (high land) which is conducive to wheat crop production.

It is bordered by on the south by Enemorina Eaner, on the west by the Oromia Region, on the north by the Wabe River which separates it from Abeshge and Kebena, on the east by Ezha, and on the southeast by Gumer and Geta.The district covers a total land area of 57315 hectare. The altitude in the district ranges from 1200 to 2600 meters. The district mean annual temperature is around 17.6^0C to 20^0C. The average annual rain fall of the district is 800mm to 1400mm. The district 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 (ChWARDO, 2020).

According to the CSA 2012 E.C- final report, the total number of rural households in 38 rural kebeles in the ditrict is 28713. The total district population is 124,094 out of which 60,020 are male and 64,073 are female

The dominant economic base of Cheha Woreda is agricultural practice with both crop production and animal husbandry. It is clear that greater part of the land is used for crop production and the major cereal crops produced are wheat, maize, teff and pulses (beans, pea). Wheat is a cereal grown primarily in this district as compare to other cereals. However, it is characterized by lack of access to modern technology, low productivity, dependency on rainfall and lack of irrigation practice. As a result, the sector remains subsistence in its nature (ChWARDO, 2019).

Figure 3.1 study area map



Source: GZFED office (2021)

3.2. Type and Source of Data

To generate appropriate data both qualitative and quantitative data collected from both primary and secondary data sources. However, due to the nature of smallholder farm's studies, primary data source dominantly used. Primary data collected from both technology adopter and non-adopter households including other concerned bodies. As it was stated in CSA (2017) the most effective evaluation in primary data collection is the one that combines qualitative and quantitative components together. Hence, this research employs the combination of both qualitative and quantitative methods. Qualitative method is used to capture data pertaining wheat producers attitude and willingness to adopt wheat row planting using semi-structured questionnaire. While, quantitative data collected from sample households using questionnaire depending on its demographic characteristics and other basic related information's. With regard to secondary source, data collected from review of different document which include relevant literatures, related publications, journal articles written by different scholars, Woreda and Kebeles' Administrations, office documents and annual statistical reports of Agricultural and Rural Development and Finance and Economic Development Offices of Cheha district, Gurage zone and SNNPR.

3.3. Sampling Techniques and Sample Size

Two-stage sampling technique applied so as to reach at the selection of a sample of small holder households in this study. Cheha woreda is purposively chosen as potential wheat belt area due to the fact that this district is appropriate because there is a wide practice of wheat row planting and its coverage from the total cultivated land in the district is better than others. Wheat row planting technology has been introduced there before and experienced in a well manner. In the first stage, the woreda is purposively chosen as potential wheat belt area among others. By taking the available resources into account, out of the 38 kebeles of Cheha woreda,there are 15 wheat producing kebeles, out of this five potential wheat producing kebeles (namely Moche, Yejoka, Goha, Enate and Awkakir) selected randomly(lottery method). Likewise, the selection of these five sample kebeles was based on the level of promotion done on wheat row planting technique. Depending on the estimation of the woreda; Moche, Yejoka, Goha, Enate and Awkakir hold the largest area of agricultural land of all other rural kebeles inside the woreda. Secondly, wheat producers in the selected kebeles identified.

To determine the sample size of the study area, the researcher use Yamane's formula (1967) (cited in Israel, 1992), with 95% confidence levels. The reason for using this formula is because this kind of formula helps to get manageable sample size for the researches that compose large number of population.

Hence, the sample size for each kebele determined by using proportionate sampling techniques. Finally, 324 respondents 130 adopters and 194 non adopters included in the study by using simple random sampling techniques from the list of households within the selected Kebeles targeted to select the samples.

$n=\frac{N}{1+N(e)2}$ where; …….. (1)

n=sample size

N=Sample frame population of wheat farmers.

e=Sampling error at 5% (0.05)

$$n=\frac{1,715}{1+1,715(0.05)^2}=\frac{1,715}{5.2875}=324$$

Table 3.1 Sampled farmers of five Kebele

S. No	Sampled Kebeles	**Total wheat Producing farmers**	Ways of compute	Sample proportion
1	Moche	406	406*324/1715	77
2	Yejoka	302	302*324/1715	57
3	Goha	394	394*324/1715	75
4	Enate	288	288*324/1715	54
5	Awkakir	325	325*324/1715	61
	Total	1715		**324**

Source: ChWARDO (2021)

3.4. Method of Data analysis

Both descriptive and econometric data analysis techniques applied in this study. The descriptive analysis is used to discuss the situation of wheat row planting by using frequencies, means, and maximum and minimum values whereas the econometric analysis is used to identify the impact of wheat row planting technology adoption on wheat yield among small household farmers level.

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). As Bernard et al. (2010), stated there are three potential sources of bias. The first one is that participant households 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 have a direct effect on outcome of interest. Secondly, the difference arises because of unobservable characteristic of the community as well as household. For example, the existence of a project in part driven by particularly dynamic local leaders at community level or individual member of the household special network as well as 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 significantly influence behavior. Thirdly, externalities (spillover effect) exerted by project on nonparticipants. Having such problems, differences between participants and non-participants, totally or partially, reflect initial differences between the two groups.

3.4.1. The Impact of wheat row planting on small household

To deal with the observable characteristics of intervention propensity score matching (PSM) is suitable method to apply. Choosing an appropriate model and analytical technique rely on the type of variable used. Now a day’s PSM is popular method for impact evaluation studies in many applications of interest due to the dimensionality of the observable characteristics is high. This matching method tries to pick an ideal comparison matching based on propensity score in which comparison group is matched with the treatment group on the basis of asetasset of observed characteristics as the base line survey was not conducted prior to the intervention on the row planting technology in the study area to compare the before and after intervention difference. Hence, it is useful to researchers with time constraints and do not have baseline data. (Raval lion, 2005; Geremew et al., 2016). Here the dependent variable of interest is binary that takes a value of 0 and 1. Assessing the impact of any intervention necessitates 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 any program intervention requires identifying the average treatment effect on the treated (ATT). The average treatment effect on the treated can be 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 a program participants had they not participated (Rosenbaum and Rubin, 1983).

Impact evaluation is the work of studying whether the changes in well-being are indeed due to the intervention and not too ther factors (Khandkeretal, 2010). Therefore, the impact of sowing wheat in line on smallholder farmer's yield will be estimated by using propensity score matching based on the observable individual household characteristics whose magnitude ranges between 0 and 1 in this particular study especially by incorporating the sensitivity analysis for unobservable individual household characteristics. Some important observable variables used in propensity score estimation of this particular study are: sex of the household head, age of the household head, educational status of the household head, family size, livestock ownership, farmers participation in agricultural training and field day demonstration, off farm participation, access to media (information), access to extension agent service and fertilizer usage.

According to Rosenbaum and Rubin (1983), let YRP be the outcome of row planting of wheat Beneficiaries whereas $Ynon$ RP be the outcome of non- row planting of wheat beneficiaries. For each individual household, only YRP or $YnonRP$is observed, that leads to a missing data problem. In estimating the propensity score matching, the dependent variable is participation in the row planting of wheat practice and let Di represents the participation indicator equaling 1 with probability of □□if the household is practicing in line sowing and 0 with probability of 1- □□otherwise. Again, let X denotes a vector of observed individual characteristics used as conditioning variables. Here in this case the average impact of the treatment on the treated (ATT) which is the most common evaluation parameter of interest is given as:

ATT = E ($YRP - Ynon - RP/D = 1, X$) = E ($YRP /D = 1$) – E ($YnonRP/D = 1$) ----------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. E (/ Di = 1, X). The mean outcome in the non-row planting beneficiaries ($Ynon - RP/ Di = 1$, X) is not observed.

Let P =Pr (D =1/X) denote the probability of participating in the practices of sowing in line of wheat i.e., the Propensity Score. Propensity Score Matching (PSM) constructs a statistical comparison group (non-row planting of wheat beneficiaries) by matching observations on sowing in line of wheat beneficiaries to non- sowing in line of wheat beneficiaries on similar values of propensity score.

Propensity score timation estimation procedure:- Propensity score estimation is the first step in PSM technique. When estimating the propensity score, two choices have to be made. The first one concerns the model to be used for the estimation, and the second one the variables to be included in this model. In

principle any discrete choice model can be used. Preference for logit or probit models (compared to linear probability models) derives from the well-known short comings of the line a probability model, especially the unlike of the functional form when the response variable is highly skewed and predictions that are outside the [0,1] bounds of probabilities. For the binary treatment case, where we estimate the probability of row planting of wheat beneficiary vs non- row planting of wheat beneficiaries, logit and probit models usually yield similar results (Caliendo and Kopeinig, 2005). For this particular study, binary logit model will be used to estimate propensity score.

Regarding, the choice of variables Smith and Todd (2005) suggested that economic theory, a sound knowledge of previous research and also information about the institutional settings should guide there searcher in building up the model. However, concerning the inclusion or exclusion of co variates in the propensity score model the matching strategy builds on the Conditional Independence Assumption, requiring that the outcome variable(s) must be independent of treatment conditional on the propensity score.

So, as it was stated by Rosenbaum and Rubin (1983) the effectiveness of PSM estimators on impact assessment depends on two basic assumptions, namely: on conditional independence and common support assumptions.

i) **Conditional Independence Assumption (CIA):**

As this assumption states that given a set of observable covariates (X) which are not affected by participation (in our case sowing wheat in line*)*; potential outcomes i.e. the household income holding are independent of participation assignment. That is both the row planting and non- row planting beneficiaries' outcome is independent of the treatment status.

$Y^{RP}, Y^{non^{-}RP} \perp D|X$ ----------3.2

$$E(Y^{RP}|P, Di = 1) - E(Y^{non^{-}RP}|P, Di = 0) \text{ ---------- } 3.3$$

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.

ii) Common Support Assumption (CSA):

Assumption of Common Support which indicated that p(x) lies between 0 and 1, and this restriction indicated that the test of the balancing property is performed only on the observations whose PSM fall to the common support region of the PSM of adopters and non-adopters (Becker and Ichino, 2002)

$0 < Pr\ (D = 1\ |X) < 1$ ---------- 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:

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

Building on these underlying assumptions, Propensity Score Matching provides a valid method for estimating ($Y^{non\ -RP}|Di = 1, X$) and obtaining unbiased estimates of ATT (Rosenbaum and Rubin, 1983).

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:

$$ATTpsm = E\ \mathrm{p}\ (x)\ (Y^{RP} - Y^{non\ -RP}|Di = 1, X)$$

$$= E\ \mathrm{p}\ (x)\ \{\mathrm{E}\ (Y^{RP} - Y^{non\ -RP}|Di = 1, P\ (X_i)\}$$

$$= E\ \mathrm{p}\ (x)\ \{E\ (Y^{RP}|Di = 1, P\ (X_i)) - E\ (Y^{non\ -RP}|Di = 1, P\ (X_i)\}\ \ldots\ldots\ldots 3.6$$

The perception is that two individual households with the same probability of participation 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 derived by binary response models.

The propensity score can then be defined as:

$$(X) = Pr\ (D = 1\ |X) = (X_1 + \dots\ \dots\ \dots + \beta_i X_i) = (X\beta) = e^{X\beta} \dots\dots\dots\dots\dots\dots\dots\ 3.7$$

Where $(X\beta)$ 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.

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 equipment's. Distance from FTC and social network are exclusionary variables that can make the Decision equation better. The coefficient αi 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:

$D = \acute{\alpha}_i Z_i + \mu_i$

$Y = \beta_i X_i + \acute{\alpha}_i D_i + \varepsilon_i$

Where the error terms (μ_i and ε_i) are assumed to follow a bivariate normal distribution with mean 0, 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 wheat on household yield, 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.

3.4.2. 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 Bilaliib et al.(2017),their consideration in tandem have advantageous because they can be used as a way of measuring the robustness of the results of impact estimates.

3.5. Sensitivity Analysis

Propensity Score Matching controls only the observable variables, included in the propensity score, to match both the treated and control groups, in our case both wheat row planting adopters and non-adopters, of the smallholder households. However, unobservable characteristics are left out of consideration (Caliendo and Kopeing (2008) Matching has become a popular method to estimate average treatment effects. It is based on the conditional independence or un confoundedness assumption which states that all variables simultaneously influencing the participation decision and outcome variables should be considered .The estimation of treatment effects with matching estimators is based on the selection on observable characteristics. However, a hidden bias might arise if there are unobservable variables which affect assignment into treatment and the outcome variable at the same time (Becker and Caliendo, 2007; Rosenbaum, 2002).

Of course PSM is the best method to impact evaluation of observable characteristics with time constraint and working in the absence of baseline data. However, one cannot be entirely sure that he/she has truly included all relevant covariates in the first stage of the matching model and effectively satisfied the conditional independence assumption that assures the effectiveness of PSM model. Since the sensitivity analysis supports the robustness of estimated results of the intervention included , in this study, mainly to assure whether the inference taken about the impact of new row-planting technologies adoption have better wheat yield increment over the adopter small holder households is reliable or not.

3.6. Statistical and Specification Tests

Before executing the final model regressions, all the hypothesized explanatory variables are checked for the existence of statistical problems such as multicollinearity problems. From econometrics point of view, one of the assumptions of the Classical Linear Regression Model (CLRM) is that there is no exact linear relationship exists between any of the explanatory variables. When this assumption is violated, we speak of perfect multicollinearity. If all explanatory variables are uncorrelated with each other, we speak of absence of multicollinearity. These are the two extreme cases and may exist in practice. So in the construction of an econometric model, it may happen that two or more variables giving rise to the same piece of information are included, that is, we may have unnecessarily included related variables because multicollinearity is not a statistical problem rather it is a data (sample) problem. 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. In addition, 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, 2012). There are various methods suggested to detect the existence of multicollinearity problem between the models of explanatory variables. Among these methods, variance - inflating factor (VIF) technique is commonly used and also it will be employed in the study to detect multicollinearity problem among continuous explanatory variables. VIF shows how the variance of an estimator is inflated by the presence of multicollinearity (Gujarati, 2004). According to Gujarati (2004), the larger the value of VIF indicates the more collinearity among one or more model explanatory variables. 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 (X_i) to zero, the greater the degree of collinearity of that variable with the other regresses. In contrast, the closer TOL of X_i is to 1, the greater the evidence that X_i is not collinear with the other regresses (Ibid) Likewise, contingency coefficient (CC) method was used to detect the degree of association among discrete explanatory variables. The discrete/dummy variables are said to be collinear if the value of contingency coefficient (CC) is greater than 0.75 (Woodridge, 2012).

3.7. Definition and measurement of Variable

3.7.1 The Dependent Variable:

In this study participation in row planting technology adoption is the first step in propensity score matching procedure. The variable is dummy (given a value 1 if the household participates in wheat row planting technology adoption and 0or non-participants). For the second step to match the model household wheat crop output is a continuous variable that is measured in quintals.

3.7.2. Definition of Explanatory variables and hypothesized relations

Explanatory variables are those variables which might influence the impact of wheat row planting technology on households output. These variables include, citrus paribus, household‘s personal and demographic variables, economic variables, technological variable and institutional variables. Let discuss on each of them as follows:

i. Sex of the household: It is a dummy variable, refers to the sex of the household head taking a value of 1 for male and 0 for female. As the study of Worku and Yishak (2017) shown that if other factors assumed to be constant, the probabilities of male household heads to be adopter increase by a factor of 26.304. Hence, male headed households have the higher probabilities of being adopter than their female counterparts. Because male household heads would have better strength and labor and access to agricultural information regarding the new technologies as compared to female household heads. Most agricultural input decisions in Ethiopia are influenced by decision of the male household heads .Therefore, this variable can be hypothesized as male-headed households are more likely to adopt wheat row planting technology package than female-headed household heads.

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ii. Age of the household head: This variable is measured in years as a continuous determinant factor. The study done by Negesse et al (2019) implied that this variable affects adoption of row planting wheat technology negatively and significant at 1% level of significant (P = 0.003) between adopters and non-adopters of row planting wheat technology. The odds ratio (0.95) shows that odds ratio in favor of adopting row planting of wheat technology decreases by a factor of 0.95, as the age of the small farm household head increases by 1 year. Therefore, a farmer with higher age has less chance to adopt wheat row planting technique. The elders have less interest to adopt improved wheat row planting practices because it needs high physical labor.

On contrary, the age of the household is the proxy for the experience of the household head in farming. The result indicated that age of the household heads influenced wheat production inefficiency negatively at 5% level of significance. This suggested that older farmers were more efficient than their young counterparts. It is decisive in determining efficiency. The knowledge, the skills as well as the physical capability of farmers is likely to increase as their age increases (Moges et al., 2018).

iii. Education level: It is a dummy variable, refers to the education level of the household head taking a value of 1 for literate and 0 for otherwise (illiterate). Generally it is recognized that education enables individuals with the necessary knowledge of how to make their living decision well. Thus, in this study, it is believed that those who are literate and have at least some formal education chance are better to adopt the new row planting technology than those of illiterate.

iV. Size of family labor: is a continuous variable that refers the number of farm household family labor force or family member in working age group. The presence of active working family member expected to affect the row planting technology adoption positively compared to those of with less labor force. This is because agricultural production in general and row planting technology adoption in particular requires strong labor force in all process of land cultivation, in line sowing system etc.

V. Tropical Livestock unit (TLU)/ Livestock ownership: this variable correlated positively with adoption of row planting. 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. Because, being other things constant, having many oxen make them possible to participate in row planting technology of the wheat crop.

Vi. Agricultural Training and Field Day: It is a dummy variable, the household head taking Participation in FTC training a value 1, and 0 otherwise. Training is one of the extension events where

farmers get practical skill and technical information for the new wheat row planting technology. Because farmers who got training on wheat row planting had higher probability of adopting row planting method compared to those who did not get training. Hence, it will be hypothesized that participating in agricultural training and attending field day demonstration had positively and significantly influenced the probability of adoption of wheat row planting technology.

Vii. Off-farm participation: It is a dummy variable that takes a value of 1 if the household participates in off-farm activity and 0 for non-participant. This is a measure of a household member participating in non–farming activities and generates an income in ETB. Participation in off-farm activity promotes the capacity to invest in new agricultural technologies and hence in this study it is hypothesized that it may affects farmers' row planting agricultural technology adoption decision positively since off-farm income helps the households to generate additional income that can help to improve their agricultural practices.

Viii. Access to media (information): This is a qualitative variable taking value 1 if farmers have access to agricultural information and 0 otherwise. Since the adoption process starts with getting awareness about the new technology, whether through media advertisement, extension agents, or social networks it is an important variable in disseminating awareness regarding to different activities including adoption decision of new agricultural technologies by small holder farmers, and economically meaning full to affect the probability of adoption of row-planting use. Therefore, it is expected that access to information (affects smallholder farm house hold row planting technology adoption decision positively as it enables them to have awareness with the merits of the new technology.

ix. Access to extension agent: It is a dummy variable. Access to extension agent support (if have access value is 1, and 0 otherwise) it is positively related with adoption of row planting wheat technology. As result of the study indicated that contact with extension agent was positively and significantly related to adoption of wheat row planting at 1% significance level. The variable accounted for 9.14% of the variation in the adoption of wheat row planting (Yalemwork, 2018**).** Since farmers receive a number of services from extension centers including technical services on its production, it is expected that farmers who lives near to such service center are likely to have regular contacts with agricultural experts, hence motivated to participate in wheat row planting technology.

x. Inorganic fertilizer: is a continuous variable that refers Fertilizer in kg per hectare is positive and significantly different from zero, indicating that farmers who apply chemical fertilizer have a higher

probability of planting their rice seeds in rows. The possible reason is that the row-planting method makes the application of agrochemicals easier, since row-spaces are left for an applicator to freely walk through the farm, unlike with random planting (Donkor et al., 2016).Table 3.2 Table of explanatory variables

Variables	Nature of variable	Variable definition and measurement	Expected effect /Sign /
I. Dependent variable			
wheat row planting technology	Binary	1 if the household is wheat row planting user, 0, otherwise.	
Outcome variable	Continuous	Annual wheat yield per hectare in quintal	
II. Explanatory variable			
Sex of the household:	Dummy	sex of the household head (if female=0, 1, otherwise)	+
Age of the farm household head	Continuous	Age of the household head in year	+/_
Educational status of the household head	Dummy	Educational status of the house hold Head (1 literate 0 otherwise).	+
Size of family labor	Continuous	household labor force or number of family in working age	+
Tropical livestock ownership	Continuous	Livestock ownership of the household in TLU	+
Participation in Agricultural training and field day demonstration	Dummy	Participation in FTC training =1, 0 Otherwise	+
Of farm-	Dummy	Off-farm participation of the household (1=Yes, 0=No)	+
Participation Access to media	Dummy	Access to media of the household head (1=Yes, 0= No)	+

Access to extension	Dummy	Access to extension agent support (if have access =1, 0 Otherwise)	+
Quantity of fertilizer applied	Continuous	Fertilizer in kg per hectare	+

Source: Own developed based on literature review and area specific (2021 GC)

CHAPTER FOUR

4 RESULT AND DISCUSSION

In this chapter the results of the findings are interpreted accordingly and discussed in detail. For the purpose of identifying the association and relationship between dependent and independent variables the study used both descriptive analyses as well as econometrics models. The Chi-square and T-test were employed to identify the significantly association and mean difference between dependent and independent variables. To calculate the significant mean difference between wheat row planting user households and non-user households, if there is any, propensity score matching was used.

4.1 Descriptive Statistics

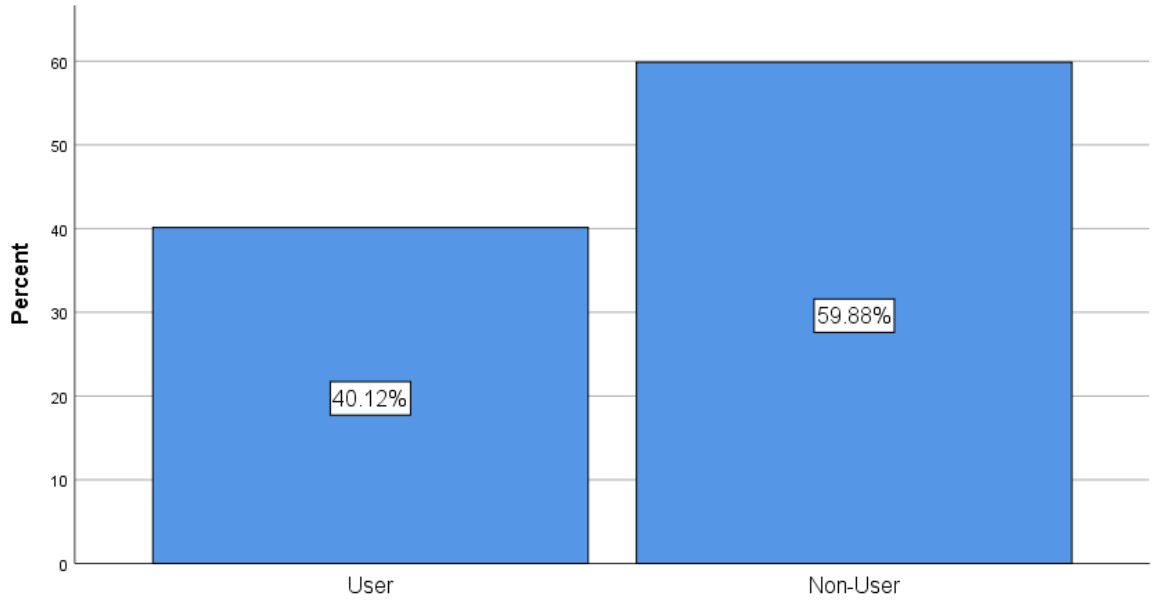


Fig 4.1 Bar chart of wheat row planting user and non-user households

The above bar chart shows from the total of 324 sample size of the selected household's 130 (40.12%) and the remaining194 (59.88%) of them are wheat row planting user and non-user households respectively.

Table 4.1 Chi-square Test of Association for Demographic and Social-economic Characteristics of Respondents

Variables	**Categories**	**User (n= 130)**		**Non-User(n=194)**		**P-Value**
		Count	**%**	**Count**	**%**	
HH Sex	Male	119	91.5%	180	92.8%	0.681
	Female	11	8.5%	14	7.2%	
HH Occupation	Farming own land	108	83.1%	166	85.6%	0.771
	Non-farm casual work	1	0.8%	2	1.0%	
	Regular job	21	16.2%	26	13.4%	
Member of social group	Yes	128	98.5%	192	99.0%	0.460
	No	2	1.5%	1	0.5%	
Agricultural agents service	Yes	126	96.9%	181	93.3%	0.152
	No	4	3.1%	13	6.7%	
Adoption impacts	Increased HH income	111	85.4%	181	93.3%	0.016*
	Reduce fertilizer consumption	6	4.6%	8	4.1%	
	Minimizes seeding rate	13	10.0%	5	2.6%	
wheat crop production and sources	Market	2	1.5%	188	96.9%	0.000**
	Board	70	53.8%	6	3.1%	
	Cooperatives	58	44.6%	0	0.0%	
Promising Sowing method	Broadcasting	0	0.0%	15	7.7%	0.001**
	Row planting	130	100.0%	173	89.2%	
	Both	0	0.0%	6	3.1%	
Last two years used varieties	Local	13	10.0%	117	60.3%	0.000**
	Improved	117	90.0%	70	36.1%	
	Both	0	0.0%	7	3.6%	
Sowing method	Row planting	129	99.2%	8	4.1%	0.000**
	Broadcasting	1	0.8%	186	95.9%	

Source: Own survey data (2022); NB: *p<0.05; **p<0.01

From Table 4.1 it can be observed that, from the 130 household wheat row planting user 119 (91.5%) households are headed by male member of the household while the remaining 11(8.5%) are headed by female head households. Looking at the non-users from the total of 194 respondents, 180 (92.8%) household heads are male and while 14 (7.2 %) are headed by female. Most households, both for users and non-users are male headed.

Comparing the household head Occupation status of user and non-user households, non-user households 166 (85.6%) tend to be farming own land than that of user's households 108 (83.1%). Regarding the membership user households are a member of any social group 128 (98.5%) and the remaining non-user households are a member of any social group 192 (99.0%).

The above table also displays the Agricultural agents service of households. From 130 user households are 128 (98.5%) get service from agricultural agents. Looking at the non-users from 194 sample households 181(93.3%) are get service from agricultural agents. Both user and non-user households are responded that regarding the impact of using wheat row planting will increase households' income 111(85.4%) and 181(93.3%) respectively. The table also shows, user households are used from Board 70 (53.8%) and Cooperatives 58 (44.6%) agricultural inputs for wheat crop production and sources where as non-user households are used from market 188(96.9%). User and non-use household 130 (100.0%) and 173 (89.2%) respectively responded that row planting method is best and the more promising in their community.

In the last two years production season kind of wheat seed varieties used by user households are improved 117 (90.0%) and non-user households were used local 117 (60.3%) and improved 70 (36.1%). Row planting 129 (99.2%) method of sowing was used in wheat crop production by user household and Broadcasting method of sowing was mostly used 186 (95.9%) by non-user households.

Finally, Adoption impacts, wheat crop production and sources, Promising Sowing method, Last two years used varieties and Sowing method are significant associated factors with wheat row planting user and non-user households based on chi-square test of association result in the above table. This test result identified that to give more emphasizing for above variables and by intervening their contribution for adoption impacts it is an indication of increasing wheat crop production for farmers. The study analyzed accordingly for continuous variables in more detailed manner. The following table listed the continuous variable in comparison between user and non-user households.

Table 4.2 Independent T-test of mean difference for Continuous Variables

Variables		**N**	**Mean**	**Std.dev.**	**t-test for Equality of Means**		
					T-Value	**D.F**	**P-Value**
Total wheat yield	User	130	19.75	4.785	14.677	322	0.000***
	Non- User	194	11.99	4.587			
HH Age	User	130	45.18	9.790	-.587	322	0.558
	Non- User	194	45.89	11.028			
Family size	User	130	5.07	1.301	-.636	322	0.525
	Non- User	194	5.15	.968			

Source: Own survey data (2022); NB: ***p<0.001

Total wheat yield and Adoption of wheat row

The average total wheat yields 19.75 and 11.99 for both User and Non- User respectively. The mean difference was found to be statistically significant with t-value of 14.677. The t-value implies that there is a significant difference between the mean family size of the users and non-users' households at ($P < 0.001$) level of significance.**Household age and Adoption of wheat row planting**

The average household age of the total 324 sample households is 45.18 and 45.89 for both User and Non-User respectively. This mean variation was found to be not statistically significant with t-value of - 0.587; and, this t-value shows there is no significant difference between the mean age of users and non-users at($P = 0.558$) level of significance.

Household size and Adoption of wheat row

From Table 4.2 it can be seen that the average family size for the 324 sample households is 5.07 and 5.15 for both User and Non- User respectively. The mean difference was found to be not statistically significant with t-value of -0.636. The t-value implies that there is no a significant difference between the mean family size of the users and non-users households at ($P = 0.525$) level of significance.

4.3. Econometrics Analysis

4.3.1 Probit Model Estimation of Factors Affecting of Adoption of wheat in row

To determine factors influencing adoption of wheat row, a Probit model is estimated. Based on the results of multivariate analysis, a model containing seven selected predictor interaction terms were included in the multivariate analysis. Using the stepwise(likelihood ratio) method, four of the seven predictor variables (Household head Skill; HH Age; HH Occupation and Total wheat yield) have a significant joint impact in determining household adoption of wheat in row. The overall model is proven, as it is statically significant at a p-value of 0.000. The pseudo-R-squared is found about 0.4158, meaning all the explanatory important variables included in the model explain 41.58% of the probability of household's adoption of wheat in row. The LR chi2(7) 181.47 with a P- value (Prob>ch2) 0.000also tells the probit model as a whole is statically significant. The signs of the regression coefficients of the model fulfill the underlying assumption and the corresponding p-values imply that the predictor variables included in the multivariate model have a significant joint influence on the outcome variable.

Table 4.3 Estimation of Probit Model

Variables	**Coef.**	**Std. Err.**	**Z**	**P>z**	**[95% Conf. Interval]**		**dy/dx**
HHAge	.0213753	.010392	2.06	0.040*	.0010073	.0417433	.0046334
HHSex	-.2435742	.3625569	-0.67	0.502	-.9541727	.4670243	-.0527977
HHSKI	.4194668	.2017463	2.08	0.038*	.0240514	.8148823	.0909246
HHEDLE	.0140056	.0377098	0.37	0.710	-.0599042	.0879153	.0030359
HHOccu	.251392	.0738351	3.40	0.001**	.106678	.3961061	.0544923
FAMSIZ	-.1085559	.0846121	-1.28	0.199	-.2743926	.0572809	-.0235308
TWYPH	.2298411	.0232285	9.89	0.000**	.184314	.2753681	.0498209
_cons	-6.478606	1.193306	-5.43	0.000	-8.817443	-4.139769	
Number of obs= 324		LR chi2(7) = 181.47		Prob > chi2 = 0.0000			
Log likelihood = -127.48404		Pseudo R2 = 0.4158					

*Source: Own survey data (2022) * Significant at 5%. ** Significant at 1%.*

The marginal effect results provided in table: 4.3 above show that keeping other factors constant, an increase the age of a household by one-year increases probability of adopting wheat in row by 0.46(0.46%). Again, it is statically significant at 5 % significance level. Household head skill status of a farmer had a positive and significant influence on the adoption of improved wheat varieties. The result of key informant interview indicated better skill attainment of farmers could increase adoption of improved wheat varieties.

4.3.2 Propensity Score matching method for the impact of wheat row planting

4.3.1.1. Model Diagnosis Test

To compare the outcome of treated and non-treated groups, propensity score matching is the best option for the observational survey. Because the observational survey considers the same characteristics in both treated and non-treated group. Thus, before estimating the impact of wheat row planting on household total wheat yield per hectare in quintal, a good balancing and common support (overlapping) of the covariate variables is necessary.

Table 4.4 Estimation of propensity score

Variables	Coefficients	Std. Err.	P-Value
Household head Age of respondents	-.0057843	.0080578	0.473
Household head sex of respondents	.1924255	.300102	0.521
Household head Education level	.0665708	.0339854	0.050**
Household head Skill	.2848623	.1568635	0.069*
Household head Occupation	-.0340724	.0621525	0.584
Extension service in years	.1793559	.0663759	0.007***
Production times within a year before adoption row planting	.4316057	.1691453	0.011***
Variety used during adoption	1.203347	.1588325	0.000***
Constant	-362.8112	132.9885	0.006***
Number of observations =	324		
Pseudo R2 =	0.1850		
chi2(8) =	79.61		
Prob > chi2 =	0.0000		
Log likelihood =	-175.2986		

Source: Own survey data (2022) * Significant at 10%. ** Significant at 5%. *** Significant at 1%.

Based on P score Stata-14 command output compiled in table 4.3 the estimation of propensity score using probit model result show, there is a good overlap indicating the common support condition is satisfied. According to the estimated propensity score result from proposed independent variables such as, Household head Education level, Household head Skill, Extension service in years, Production times within a year before adoption row planting and Variety used during adoption, with the P-value in-between of 0.000 and 0.050 are statistically significant. As it can be observed from the appendix below. The other important assumption to estimated propensity score matching is that the balancing property should be satisfied (Rosenbaum and Rubin, 1983). Here the balancing property is satisfied for the estimated propensity score. (See the appendix). Both balancing and overlap of the covariate variables between treated and non-treated groups are the same for total wheat yield per hectare in quintal.

4.2 Impact of row planting adoption on wheat crop production in quintal

Row planting adoption have an advantage on the wheat crop output level of the household. Many researches focus on the factors affecting row planting adoption; however, in this research the researcher is saw the impact of row planting adoption on household wheat crop output in quintal. In this section, to see whether the adoption of row planting has an impact on user and non-user households or not, the researcher used propensity score matching method. The propensity scores matching shows whether the treatment have positive impact or not. The below table below shows the average treatment effect on treated group as result of adoption of row planting.

Table 4.5 The average Treatment effect on Treated (ATT)-Yield

Type of matching method	Users	Non-users	ATT	Std. Err.	t-value
Nearest Neighborhood	130	74	7.115	0.813	8.749*
Radius matching	130	173	7.165	0.686	10.450*
Kernel matching	130	74	7.115	0.665	10.695*
Stratification method	130	173	7.722	0.719	10.740*

Source: computed from own survey (2022); NB: *statistically significant

To identify the impact of row planting on households' wheat yield production four matching methods were used. These methods are; nearest neighborhood, radius, kernel and stratification matching methods. As we observe in Table 4.5, the average treatment effects on treated with nearest neighborhood matching method; the treatment group is 130, while the number of controls is 74after matching. Neighborhood

matching method reveals the difference of average income of 130treatment groups and the average income of 74 control groups is around 7.115 Quintals produced annually.

Therefore, 7.115 Quintal is the average treatment effect on treated group which is the effect of row planting on wheat yield production level of the households. Thus, user households can earn additional yield than that of non-user household. The average treatment effect of the treated group shows positive impact. This implies adopting raw planting increases the yield of a household. This result is also statistically significant at t-value of 8.75. Therefore, adopting raw planting have a positive impact on the yield of households with neighborhood matching method.

The same result is obtained from radius matching methods. Under this method, the total number of treated group is 130 while the number of controls is 173 after matching. The difference in average yield between treated and non-treated group 7.165 Quintals per annum. This result is the average treatment effect on the treated group. This implies adopting raw planting has a positive impact. According to this result, user households earn more income than that of non- users. It is also statistically significant at t- value of 10.45. Therefore, under radius method adoption raw planting has a positive impact in increasing yield level of households.

The other matching method to see the impact of row planting on household wheat yield production in quintals is with kernel matching method. It also shows adopting row planting in the study area has a positive impact on household yield production. Under this matching method, the average treatment effect of row planting on treated group, on average, production additional yield of 7.115 Quintals yearly. Meaning, the difference in average income between the control and the treatment group is the effect of adopting raw planting. So, this method shows positive impact and it is also statistically significant at t-value of 10.70.

The final method to see the impact of adopting wheat crop row planting on household yield production is stratification matching method. This method reveals, the adoption of row planting has a positive impact on the yield production level of the household. It is also statically significant at t-value 10.74. This indicates that, the difference in the average yield between the130 treated group and 173 non treated group shows the treatment group has difference in average yield production. Consequently, the result from the four matching methods reveals, adopting small scale row planting has a positive impact on the households' yield output. This might be as a result of households engaging in different livelihood diversification activities and other associated factors identified by this study like: Household head Education level;

Extension service in years; Production times within a year before adoption row planting; Variety used during adoption and allocating more time on agricultural activities. Consequently, it can be concluded that, the overall the results are remarkably robust and the analysis support the robustness of the matching estimates.

4.3. Sensitivity Analysis

According to Dehejia (2002), sensitivity analysis is the final diagnostic that is performed to check the sensitivity of the estimated treatment effect to small changes in the specification of the propensity score; this is a useful diagnostic on the quality of the comparison group.

Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. Based on this principle, sensitivity analysis is tested to check whether unobserved covariates have effect on the results by creating biases or not. Furthermore, after ATT is found, it is vital to test whether the estimated ATT results are effective or not. And hence, sensitivity analysis was undertaken to detect the identification of conditional independence assumption if it is affected by the confounder or not. Table 4.6 below revealed the sensitivity analysis of the outcome ATT values of wheat yield to the confounders. The sensitivity analysis result shows that, the significance level of ATT is unaffected and is insensitive to external change. Therefore, the conditional independence assumption remains to be significant and the results were not sensitive to the confounders and there are no external cofounders (variables) which affect the results calculated for ATT of outcome variables wheat yield production. Table 4.6 below revealed that the sensitivity analysis of the outcome variables technical efficiency. The Gamma values from 1 to 2 has upper significance level of 8.90E-16and lower significance level 0 for wheat yield output. This result indicates that the technical efficiency is significant or robust and the ATT results of both outcome variables were not sensitive to the confounder.

Table 4.6: Sensitivity analysis for outcome variable: Wheat Yield Output

Gamma	sig+	sig-
1	0	0
1.05	0	0
1.1	0	0
1.15	0	0
1.2	0	0
1.25	0	0
1.3	0	0
1.35	0	0
1.4	0	0
1.45	1.10E-16	0
1.5	3.30E-16	0
1.55	8.90E-16	0
1.6	2.40E-15	0
1.65	6.20E-15	0
1.7	1.50E-14	0
1.75	3.50E-14	0
1.8	7.70E-14	0
1.85	1.60E-13	0
1.9	3.30E-13	0
1.95	6.50E-13	0
2	1.20E-12	0

Gamma - long odds of differential assignment due to unobserved factorssig+ - upper bound significance levelsig- - lower bound significance level

CHAPTER FIVE

5 CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

As more than 85% Ethiopian economy is depended on the agricultural sectors, the effectiveness of this sector is faced a lot of challenges and affected by different factors like fail to adopt recent introduced agricultural effective mechanism like row planting. Striving hard to sustain household yield production should be concern of researchers, policy maker and others relate government and non-government organization. Adopting row planting has a huge potential to maximize the income and annual yield production of household practicing in their day today activities of live carriers and it is also very important for country development.

This study was conducted to see the impact of row planting adoption on household wheat crop production. Five kebeles from Cheha district of Gurage zone were included in the study, SNNPR region. The research is a quasi-experimental study where it compared row planting user and non-user households. In total the study took 324 sample households, 130 user and 194 non-user households from 5 kebeles of the woreda. Different characteristics and factors were considered for user and non-user households to determine the effect row planting has on user households.

The chi-square test of association result of the study showed most of the household's characteristics are statistically significant with user and non-user households like adoption impacts, wheat crop production and sources, promising sowing method, last two years used varieties and sowing method. The independent t-test of mean difference for continuous variables like household age; household size; total wheat yield and income after in quintal shows statistically mean difference between user and nonuser households

To identify the impact of row planting technology on households' yield production the study used four matching methods; these methods are; nearest neighborhood, radius, kernel and stratification matching methods. The four matching methods revealed row planting method has an impact on yield output. Finally, based on the result of probit model shows that variables include household head education level; extension service in years; production times within a year before adoption row planting and variety used during adoption significantly associated with wheat row planting adoption.

5.2 Recommendation

Based on the findings of this study, the following recommendations are forwarded in order to improve row planting technology.

- → Household headed should be encourage to use row planting adoption due to it is increase the wheat yield production as the study finding shows.
- → Available technologies and practices that help to reduce work burden on farmers should be provided by the government bodies is essential.
- → Concerned body should provide farmers with more practical trainings under farmers‟ direct participation in the demonstration centers‟‟.
- → Mechanisms and techniques should be in place for the rural poor to take advantage of benefits of row planting technology.
- → Setting up easy referral systems where user households can go when they face difficulties, maintenance issues and spare parts.
- → Consideration must to be given towards engaging females and female-headed families to encourage their productivity.

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Annex

Questionnaire

Title: The Impact of Adopting Wheat Row Planting Technology on Yield; The Case of Small Holder Farmers - In Cheha Woreda, Gurage Zone

Dear Respondents:

I, Freweyin Degemu, am prospective graduate of Masters of Science in Development Economics at Wolkite 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

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

Thank you!

General information

1. **Date of interview**_____
2. House hold ID_____
3. Male/Female:_____
4. Age_____years
5. Years of education_____
6. Address: Village_____Kebele _____
7. Name oftheInterviewer:_____Sign:_____

I: Household Demographic status

#	Name	Age (Years)	Sex Male Female	Education level	Skill Carpenter Black smith House builder Other None	Relationship to the respondent	Occupation: education; farming own land; labor for other farmers; non-farm casual work; small trade/enterprise regular job; retired	Is the member available for work on the household farm? [a]full time; [b]part time;
1								
2								
3								
4								
5								
6								
7								

II: Technological adoption

1. Have you ever heard about sowing in line of wheat in the past?

1. Yes
2. No

2. If you heard about sowing in line where did you get that information?

I. Extension agents

II. Friends and families

III. Neighbors

IV. Social network sources

V. kebele administration

VI. Others (please specify)_____

3. As a household do you adopt wheat row planting technology?

1. Yes
2. No

4. If the answer to question number 3 is 'yes', since when did you adopt _____ years

5. If the answer to question number 3 is 'no', what is the reason for not adopting row planting of wheat?

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_____

6. Do you face labor shortage problem to practice row planting?

1. Yes

2. No

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

    1. By hiring
    2. Asking for cooperation
    3. All
    4. Other : Specify_____

8. Are you a member of any social group

    1. Yes
    2. No

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

    1. Equb
    2. Edir
    3. Farmers association
    4. All
    5. Other, specify ……

15. Do you get enough service from agricultural agents?

    1. Yes
    2. No

16. Since When do you get extension service in years_____

17. How many km is the Farmer training center(FTC) from your home_____

18. Do you get credit access in your locality?

    1. Yes
    2. No

III: Row planting contribution towards wheat production

1. Do you think that adoption of row planting has a positive impact on wheat crop production? (Put √ mark)
    1. Yes_____
    2. No_____
2. If your answer is yes, what are the positive impacts of adoption of sowing in line of wheat that you have seen? (Put √ mark)
    1. Increased household income_____
    2. Reduce fertilizer consumption_____
    3. Minimizes seeding rate_____
    4. Other specify_____
3. How many times do you produce within a year before adoption row planting_____times/year
4. How many times do you produce within a year after adoption of row planting_____times/year

1. Other income source (before and after sowing in line)

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

V: 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	

VI: Access to and utilization of farm inputs for wheat crop production

1. Which agricultural inputs do you use for wheat crop production and what are the sources?

Type of input	Specific Name	Source(tick)		
		Market	BoARD	Cooperatives
Improved seed of wheat				
Local seed of wheat				
Fertilizer	DAP			
	Urea			
	Other/ mixture/			
Chemicals	Herbicide			
	Fungicide			
	Insecticide			
Others(Specify)				

IX: Intensity of participation (adoption) of row planting using wheat variety

1. Which Method of sowing do you think is most promising in your community?
    1. Broadcasting
    2. Row planting
    3. Both

2. Why do you think is most promising?_____
3. In the last two years production season what kind of wheat seed varieties did you use?
    1. Local
    2. Improved
    3. Both
4. Which method of sowing you used in wheat crop production?
    1. Row planting
    2. Broadcasting
    3. Both
    4. transplanting
5. If your answer is row planting, to which variety you used this method?
    1. Local
    2. Improved
    3. Both
6. Did you apply fertilizer in wheat crop production?
    1. Yes
    2. No
7. If your answer is yes, to which variety you applied fertilizer?
    1. Local
    2. improved
    3. both
8. If your answer is yes, which kind of fertilizer you used?
    1. DAP
    2. Urea
    3. Both
9. If you did not apply fertilizer in wheat crop production, what is your reason _____
10. Type of fertilizer not applied yet _____

Appendix 2: probit model and marginal effect

. probit ADOPTER HHAge HHSex HHSKI HHEDLE HHOccu FAMSIZ TWYPH

Iteration 0: log likelihood = -218.21694
Iteration 1: log likelihood = -129.36871
Iteration 2: log likelihood = -127.49428
Iteration 3: log likelihood = -127.48404
Iteration 4: log likelihood = -127.48404

Probit regression Number of obs = 324
LR chi2 (7) = 181.47
Prob > chi2 = 0.0000
Log likelihood = -127.48404 Pseudo R2 = 0.4158

ADOPTER	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
HHAge	.0213753	.010392	2.06	0.040	.0010073	.0417433
HHSex	-.2435742	.3625569	-0.67	0.502	-.9541727	.4670243
HHSKI	.4194668	.2017463	2.08	0.038	.0240514	.8148823
HHEDLE	.0140056	.0377098	0.37	0.710	-.0599042	.0879153
HHOccu	.251392	.0738351	3.40	0.001	.106678	.3961061
FAMSIZ	-.1085559	.0846121	-1.28	0.199	-.2743926	.0572809
TWYPH	.2298411	.0232285	9.89	0.000	.184314	.2753681
_cons	-6.478606	1.193306	-5.43	0.000	-8.817443	-4.139769

. margins, dydx(HHAge HHSex HHSKI HHEDLE HHOccu FAMSIZ TWYPH)

Average marginal effects Number of obs = 324
Model VCE : OIM

Expression : Pr(ADOPTER), predict()
dy/dx w.r.t. : HHAge HHSex HHSKI HHEDLE HHOccu FAMSIZ TWYPH

Delta-method

dy/dx Std. Err. z P>z [95% Conf. Interval]

HHAge	.0046334	.0022087	2.10	0.036	.0003045	.0089623
HHSex	-.0527977	.0784358	-0.67	0.501	-.2065291	.1009337
HHSKI	.0909246	.0430861	2.11	0.035	.0064774	.1753718
HHEDLE	.0030359	.0081648	0.37	0.710	-.0129669	.0190386
HHOccu	.0544923	.0151355	3.60	0.000	.0248273	.0841573
FAMSIZ	-.0235308	.0182193	-1.29	0.197	-.0592401	.0121784
TWYPH	.0498209	.0017155	29.04	0.000	.0464585	.0531832

Propensity score matching estimation

pscore adopter hhage hhsex hhedle hhski hhoccu lspprp dygesiny hmtpafadrp wcvum , pscore(psincome) blockid(blockf1) comsup level(0.001)

****

Algorithm to estimate the propensity score

****

The treatment is adopter

ADOPTER	Freq.	Percent	Cum.
0	194	59.88	59.88
1	130	40.12	100.00
Total	324	100.00	

Estimation of the propensity score

note: lspprp != 1 predicts failure perfectly

lspprp dropped and 6 obs not used

Iteration 0: log likelihood = -215.10177

Iteration 1: log likelihood = -176.28588

Iteration 2: log likelihood = -175.30242

Iteration 3: log likelihood = -175.2986

Iteration 4: log likelihood = -175.2986

Probit regression Number of obs = 318

LR chi2(8) = 79.61

Prob > chi2 = 0.0000

Log likelihood = -175.2986 Pseudo R2 = 0.1850

adopter	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
hhage	-.0057843	.0080578	-0.72	0.473	-.0215773	.0100087
hhsex	.1924255	.300102	0.64	0.521	-.3957637	.7806147
hhedle	.0665708	.0339854	1.96	0.050	-.0000394	.133181
hhski	.2848623	.1568635	1.82	0.069	-.0225845	.592309
hhoccu	-.0340724	.0621525	-0.55	0.584	-.155889	.0877443
dygesiny	.1793559	.0663759	2.70	0.007	.0492615	.3094504
hmtpafadrp	.4316057	.1691453	2.55	0.011	.1000869	.7631244
wcvum	1.203347	.1588325	7.58	0.000	.8920405	1.514653
_cons	-362.8112	132.9885	-2.73	0.006	-623.4639	-102.1586

Note: the common support option has been selected

The region of common support is [.07584984, .94783665]

Description of the estimated propensity score

in region of common support

Estimated propensity score

Percentiles	Smallest		
1%	.0815905	.0758498	
5%	.0940446	.0781641	
10%	.1242112	.0814461	Obs 303
25%	.2039464	.0815905	Sum of Wgt. 303
50%	.4367396		Mean .4225217
	Largest		Std. Dev. .2263997
75%	.57686	.9131502	
90%	.7066889	.9377258	Variance .0512568
95%	.8121073	.9378981	Skewness .2111946
99%	.9131502	.9478367	Kurtosis 2.144127

****

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 blocks
****
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	ADOPTER 0	1	Total
.0758498	63	7	70
.2	41	19	60
.4	49	57	106
.6	16	32	48
.8	4	15	19
Total	173	130	303

Note: the common support option has been selected

****
End of the algorithm to estimate the pscore
****
. attnd TWYPH ADOPTER,pscore(psincome) comsup
 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
------------------------------------------------------------

     130         74      7.115      0.813      8.749

------------------------------------------------------------
Note: the numbers of treated and controls refer to actual
nearest neighbour matches
.
. attnd TWYPH ADOPTER,pscore(psincome)  comsup bootstrap

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

     130         74      7.115      0.813      8.749
------------------------------------------------------------
Note: the numbers of treated and controls refer to actual
nearest neighbour matches
Bootstrapping of standard errors

command:     attnd TWYPH ADOPTER     , pscore(psincome)   comsup
statistic:   r(attnd)
(obs=324)
Bootstrap statistics

Variable |   Reps   Observed       Bias   Std. Err.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
    bs1 |     50   7.115385   -.122114   .6652728    5.778469    8.4523  (N)
```

```
      |                              5.687302  8.251244  (P)
      |                              5.744624  8.356593 (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
-------------------------------------------------------------
    130         74       7.115       0.665      10.695
-------------------------------------------------------------
Note: the numbers of treated and controls refer to actual
nearest neighbour matches

. attr TWYPH ADOPTER ,pscore(psincome) comsup radius (0.1) bootstrap

 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
-------------------------------------------------------------
    130        173       7.165       0.611      11.719
-------------------------------------------------------------
Note: the numbers of treated and controls refer to actual
matches within radius
Bootstrapping of standard errors
command:     attr TWYPH ADOPTER     , pscore(psincome)   comsup radius(.1)
statistic:   r(attr)
(obs=324)

Bootstrap statistics

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

```
---------+--------------------------------------------------------------------
    bs1 |    50   7.165443   .0024848   .6856941    5.787489  8.543397  (N)
        |                                5.952486  8.608821  (P)
        |                                5.952486  8.608821 (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
------------------------------------------------------------
     130        173      7.165      0.686     10.450------------------------------------------------------------
Note: the numbers of treated and controls refer to actual
matches within radius
. atts TWYPH ADOPTER ,pscore(psincome) blockid (blockf1) comsup bootstrap
ATT estimation with the Stratification method
Analytical standard errors
------------------------------------------------------------
n. treat.   n. contr.        ATT   Std. Err.         t
------------------------------------------------------------
     130        173      7.722      0.584     13.221
------------------------------------------------------------
Bootstrapping of standard errors
command:     atts TWYPH ADOPTER  , pscore(psincome) blockid(blockf1) comsup
statistic:   r(atts)
(obs=324)

Bootstrap statistics

Variable |   Reps   Observed       Bias   Std. Err.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
    bs1 |    50   7.721986  -.0840904   .7189945    6.277113   9.16686  (N)
        |                                6.491168  8.947345  (P)
        |                                6.491168  8.947345 (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
130	173	7.722	0.719	10.740

Sensitivity analysis

rbounds rho, gamma(1(0.05)2)

Rosenbaum bounds for rho (N = 130 matched pairs)

Gamma	sig+	sig-	t-hat+	t-hat-	CI+	CI-
1	0	0	19	19	18	20.5
1.05	0	0	19	19.5	18	20.5
1.1	0	0	19	19.5	18	20.5
1.15	0	0	19	19.5	18	20.5
1.2	0	0	18.5	19.5	18	21
1.25	0	0	18.5	20	18	21
1.3	0	0	18.5	20	17.5	21
1.35	0	0	18.5	20	17.5	21
1.4	0	0	18.5	20	17.5	21
1.45	1.1e-16	0	18.5	20	17.5	21
1.5	3.3e-16	0	18	20.5	17.5	21.5
1.55	8.9e-16	0	18	20.5	17.5	21.5
1.6	2.4e-15	0	18	20.5	17.5	21.5
1.65	6.2e-15	0	18	20.5	17.5	21.5
1.7	1.5e-14	0	18	20.5	17	22
1.75	3.5e-14	0	18	20.5	17	22
1.8	7.7e-14	0	18	21	17	22

1.85	**1.6e-13**	**0**	**18**	**21**	**17**	**22**
1.9	**3.3e-13**	**0**	**18**	**21**	**17**	**22**
1.95	**6.5e-13**	**0**	**17.5**	**21**	**17**	**22**
2	**1.2e-12**	**0**	**17.5**	**21**	**17**	**22**

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

sig+ - upper bound significance level

sig- - lower bound significance level

t-hat+ - upper bound Hodges-Lehmann point estimate

t-hat- - lower bound Hodges-Lehmann point estimate

CI+ - upper bound confidence interval (a= .95)

CI- - lower bound confidence interval (a= .95)