

**DETERMINANTS OF RENTING-IN THRESHING MACHINE AND ITS
IMPACT ON SORGHUM THRESHING COST: THE CASE OF
HARAMAYA DISTRICT, EAST HARARGHE ZONE, OROMIA
REGIONAL STATE, ETHIOPIA**

M.Sc. Thesis

Tekalign Bedada

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Haramaya University**

**Determinants of Renting-in Threshing Machine and Its Impact on Sorghum
Threshing Cost: The Case of Haramaya District, East Hararghe Zone,
Oromia Regional State, Ethiopia**

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By

Tekalign Bedada

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Haramaya University**

APPROVAL SHEET
HARAMAYA UNIVERSITY
POST GRADUATE PROGRAM DIRECTORATE

As Thesis Research advisors, we hereby certify that we have read and evaluated this Thesis prepared, under our guidance, by **Tekalign Bedada** entitled **“Determinants of Renting-in Threshing Machine and its impact on Sorghum Threshing Cost : The Case of Haramaya District, East Hararghe Zone, Oromia Regional State, Ethiopia”**. We recommend that it be submitted as fulfilling the thesis requirement.

Lemma Zemedu (PhD)

Major Advisor

Signature

Date

Chaurasia, S.P.R (PhD)

Co-Advisor

Signature

Date

As member of the Board of Examiners of the M.Sc. Thesis Open Defense Examination, we certify that we have read evaluated the Thesis prepared by Tekalign Bedada and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the Degree of Master of Science in Agriculture (Agricultural Economics).

Chairperson

Signature

Date

Internal Examiner

Signature

Date

External Examiner

Signature

Date

Final approval and acceptance of the thesis is contingent up on the submission of its final copy to the Council of post Graduate Program (CGPG) through the Candidates Department or Department Committee

DEDICATION

I dedicate this thesis manuscript to my wife W/ro Aynalem Seyfe, and my Children Lideya Tekalign and Samuel Tekalign, for nursing me with care, love and for their dedicated company in the success of my life.

STATEMENT OF THE AUTHOR

First, I declare that, this thesis is my solely work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at the Haramaya University and is deposited at the University Library to be available to borrowers under rules of the library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Name: Tekalign Bedada Signature: _____

Place: Haramaya University, Haramaya

Date of Submission: June, 2017

BIBLIOGRAPHICAL SKETCH

The author was born in 1967 in Weliso town, South West Showa Zone from his father Bedada Ejeta and his mother Tsegaye Kabtimer. He attended his elementary school at Ras-Gobena Dachaw primary school and his secondary education at Agaro Senior Secondary School in Agaro.

He joined Haramaya University in 2006, and graduated with BA Degree in Accounting in 2008. Then he joined CEP of the Post Graduate Directorate of Haramaya University, School of Agricultural Economics and Agribusiness Management in 2013 academic year as a self-sponsored student for pursuing his M.Sc. Degree in Agricultural Economics.

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ACRONYMS AND ABBREVIATIONS

BARI	Bangladesh Agricultural Research Institute
CH	Combine Harvesting
CM	Caliper Matching
EHZARDO	Eastern Hararghe Zone Agriculture and Rural Development Office
FAO	Food and Agricultural Organization
FARC	Fedis Agricultural Research Center
GoE	Government of Ethiopia
HDARDO	Haramaya District Agricultural and Rural Development Office
HH	House Hold
HRTPC	Harar Rural Technology Promotion Center
KM	Kernel Matching
MH	Manual Harvesting
ML	Maximum Likelihood
NARS	National Agricultural Research Stations
NCAER	National Council of Applied Economic Research
NN	Nearest Neighbor
OoA	Office of Agriculture
PA's	Peasant Associations
PHCE	Population and Housing Census of Ethiopia
PSM	Propensity Score Matching
RSSI	Rice Self-Sufficiency Index
SCPI	Sustainable Crop Production Intensification
STET	Sorghum Threshing Expenditure per Ton
TLU	Tropical Livestock Unit
Tk	Take (USD1 = Tk68 in 2005/06)
VIF	Variance Inflation Factor

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Determinants of Renting-in Threshing Machine and its impact on Sorghum Threshing Cost: the Case of Haramaya District, East Hararghe Zone, Oromia Regional State, Ethiopia.

ABSTRACT

The purpose of this study was to identify and evaluate determinant factors of renting-in threshing machine and the impact of machine renting-in service on reduction of threshing cost of the household. To address the objectives the study used cross-sectional data collected from 180 machine users and non-users households in Haramaya district. Sample size of respondent from each selected two kebeles was determined using probability proportional to size sampling technique. The sample from each stratum was selected randomly using simple random sampling technique. For data analysis, descriptive statistics, econometric model and propensity score matching (PSM) technique were employed. The result of logistic regression model indicated that, education level of household head, area of cultivated land, social status of the household head, accessibility to farm technology, farmers perception and number of extension contact were the major factors that positively and significantly affected the use of renting-in thresher service for threshing the sorghum in the study area. The balancing of propensity score and covariate checked via different procedures by applying the selected matching algorithm. The process of matching thus creates a high degree of covariate balance between the participant and non-participant samples. Also, t-values showed that before matching four of selected variables statistically significant differences but after matching all of the covariates were balanced and become statistically insignificant. The low pseudo- R^2 and the insignificant likelihood ratio tests support the matching hypothesis. The result pertaining to propensity score matching revealed that renting-in sorghum threshing machine helped in reducing the cost of threshing per ton by about Birr 894.52. Based on the result of the study, it was found that introduction of the machine in the sorghum threshing area's will be beneficial in reducing the cost of threshing and timely completion threshing of grain. Therefore efforts are needed by Government, NGO's and private sectors to make multiplication and promotion of the thresher for farmers who use on their harvest and give renting service for farmers who can't purchase the machine

Keywords: Sorghum threshing machine Cost of threshing, Renting-in service, Logit model and Propensity Score Matching.

1. INRODUCTION

1.1. Background

Agriculture is very much the base of Ethiopia's economy, standing as the base and the building block of what the country is today. The agriculture sector accounts for 50% of the country's GDP, 85% of exports, and over 80% of total employment in the labor force. Ethiopia's agriculture sector, however, faces many threats. These include soil degradation due to overuse, drought, high tax rates, low subsidies, and poor infrastructure. USAID and Ethiopia's government are working together to combat such issues, by providing agricultural education, technology, and better roads. Ethiopia's agriculture sector is a healthy and important one, and it is safe to assume that it will continue to head in the positive direction for a while to come (Deloitte, 2016).

Production of cereal crops dominate Ethiopian agriculture, accounting for about 70 % of agricultural GDP. Livestock production accounts for about 32 % of agricultural GDP and draught animal power is critical for all farming systems. Over the past decade, cereal production has more than doubled to nearly 15 million tones, as a result of horizontal expansion of area and increased yields. Nevertheless, food security remains a critical issue for many households, and for the country as a whole. Moreover, expansion of the cropped area to more marginal lands has led to severe land degradation in some areas. Ethiopian agriculture is dominated by subsistence, low input-low output; rain-fed farming system (Demese *et al.*, 2010).

Sorghum is one of the main staple crops for the poorest and most food insecure people of the world. Ethiopia being the centre of origin and diversity for sorghum, the crop has been cultivated for many thousand years (Mekbib, 2009).

There is an increasing demand for sorghum on domestic and international markets due to many ethnic and dietary foods, snacks and other identity-preserved products with excellent properties appreciated by consumers (Simonyan *et al.*, 2004). Rooney (2003) reported that a major limitation in producing excellent food products from sorghum is a lack of consistent

supply of good quality grain for processing. Contaminants affect the quality of grains and make grains less attractive in appearance therefore they constitute easy habitats for pests, increase handling cost, and ultimately cause low market value (Hurburgh Jr, 1995).

In east Haraerghe the major crops produced are sorghum, maize, teff, barley, wheat, haricot bean and ground nut. The major growing areas of sorghum are found in the North-central highland of the zone, which extends from west to east. The least growing are found in the eastern part of the zone. In the zone in the year 2012, out of the total crop production, sorghum, contributed 51.88% (2.88 million quintals). The average yield being 19.74 quintals per hectare (CSA, 2012). In Haramaya district, sorghum covered an area of 13,017.5 hectares with 342,442 quintals of production and 26 quintals per hectare productivity (HDARDO, 2014).

Agricultural mechanization implies the use of various power sources and improved farm tools and equipment, with a view to reduce the drudgery of the human beings and draught animals, enhance the cropping intensity, precision and timelines of efficiency of utilization of various crop inputs and reduce the losses at different stages of crop production. The end objective of farm mechanization is to enhance the overall productivity and production with the lowest cost of production (FAO, 2013).

Though Ethiopia has a long history of agricultural practices, the development of agricultural mechanization is still minimal. Farm power is mainly dependent on oxen-draft and human muscle operating using traditional farm implements. The level of tractor-based agricultural machinery use is relatively better in wheat dominated cropping systems where harvesting and threshing are done by using combines *etc* (MoA, 2014).

The main objective of the study is to contribute to a reduction of sorghum threshing cost of the rural farmer through studying the impact of threshing machine on agricultural development. In attaining this objective, the study improves the knowledge of farmers in adoption and utilization of the technology and its economic advantage relative to traditional systems. By demonstration, scaling-up, adoption and promotion of the appropriate and sustainable existing farm machinery technologies, we should reduce threshing expenditures,

time of threshing and drudgery works. Farmers should be trained in the technology utilization and maintenance for properly exploitation of the resources. On this back ground, parallel to technology utilization through impact study, the economic benefit (profitability) should be recognized.

1.2. Statement of the Problem

Threshing of cereal grains by machine is an important part of mechanized agriculture. Threshing is the first and major post harvest operation of grain. The removal, or separation, of grains from the panicles of the stalks is termed threshing (Hossain *et al.*, 2013). Mazvimavi (1997) classified threshing and winnowing of sorghum, which accounts for 50% of total labor used in the production as an arduous task.

The traditional method of grain separation is laborious, time consuming and uneconomical. This method of threshing consumes more time, compared to other mechanical threshing method. Traditional threshing method also causes grain loss, to the extent of 6% (Miah, 1990).

Among the mechanisms through which agricultural growth has been achieved is through intensifying land use and increasing labor productivity, including through mechanization. The Agricultural Development Led Industrialization (ADLI) framework encourages adoption of improved farm power and implements (GoE, 2007). It promises to invest in the adaptive research and development of improved farm implements and to strengthen the production capacity of rural technology centers in implement manufacturing. However, the studies on the impact of mechanization in Ethiopia on crop production, productivity, income generation and cost reduction are very few.

Recently in the study area, farmers have started to use thresher for threshing the sorghum crops. Majority of farmers are using renting-in services for threshing their crops and have interest to buy sorghum threshing machine. However, in the study area there was no studies under taken on the impact of farm mechanization on reduction of cost of production. Thus, there was need to investigate whether farm households using renting-in service of machines

are economically better off than those who are using traditional methods of threshing their crops and whether there exists much gap in expenditure in crop production among farmers. In addition, the reason for conducting this study was that in Haramaya district, sorghum is produced at large scale and the problem of threshing is a common feature. However, threshing of sorghum through manual labor (*i.e.* through traditional system) has its own limitations like high cost of threshing, drudgery and needs much time in threshing compared by motorized thresher. Therefore it was thought pertinent to identify major factors affecting use of renting-in services of thresher and to measure its cost of threshing. Thus, this study is an attempt to provide empirical evidence on the impact of sorghum threshing machine renting-in service on threshing cost of sorghum and determinant factors in using the thresher.

1.3. Research Questions

This study attempts to address the following relevant research questions:

1. What are the factors determining use of renting-in service of sorghum thresher in the study area?
2. What is the impact of renting-in threshing machine on threshing cost of sorghum in the study area?

1.4. Objectives of the Study

The overall objective of the study was to assess the contribution of sorghum threshing machine in sorghum crop production. The specific objectives of the study were:

1. To identify major factors affecting use of threshing machine renting-in services, for sorghum threshing in the study area.
2. To measure impact of renting-in sorghum threshing machine on threshing cost of sorghum.

1.5. Significance of the Study

In Ethiopia East Hararghe produced 5.05 million quintals of cereals and sorghum crop produce was 2.88 million quintals (CSA, 2013). Almost all threshing and shelling operations were performed traditionally even though; a little machine threshing efforts were made. Due to manual threshing, farmers wasted their time, money and supposed to drudgery work. In the past time, with package program, the previous Harar rural technology promotion center (HRTPC) together with East Hararghe zone of agriculture and rural development office (EHZARDO) promoted few numbers of maize shellers for farmers. Machine owners used those machines for shelling their grains and also earned income through offering renting service to non owner farmers.

Now days, under Fedis agricultural research center, there are mechanization and socio economic and extension research processes which are working on development, improvement, modification, demonstration and promotion of those technologies. One of research result technology of Fedis Agricultural Research Center is FARC- sorghum thresher which was initiated by Tekalign Bedada (see Figure 1). Few numbers of these machines were disseminated on cash sale to farmers. The farmers who purchased them were using for threshing their sorghum harvest as well as generating income, through giving renting services for Haramaya, Fedis districts and Harari region. So, the result of the study may throw light on the facts whether the introduction of threshing machine for sorghum crop can be made on large scale with economic advantage or not if it proves profitable, then many more farmers would be encouraged to adopt it in the study area.



Figure.1. Sorghum threshing machine

1.6. Scope and Limitation of the Study

The study is aimed at identifying the factors that determine households' participation in using renting-in service of sorghum threshing machine and its role in reducing household threshing cost, time saving and drudgery of manual threshing in the area. The study covered only one of nineteen districts of Eastern Hararghe zone. It covered only a limited number of farmers focusing on examination of the different dimensions of threshing services and practices.

Due to limited resource and time constraint, the study was restricted to the specific nature and socio-economic set up of the Haramaya farm household. Therefore, the results and findings of the study reflected only the household livelihood of the study areas and cannot be replicated into to other locations without some changes.

2. REVIEW OF LITERATURE

2.1. Definition, Concepts and fabrication of Grain Thresher

Threshing consists of separating the grains from the portion of the plant that holds them. This separation, done by hand or machine, is obtained by threshing, by friction or by shaking the products; the difficulty of the process depends on the varieties grown, and on the moisture content and the degree of maturity of the grain. Threshing operations follow the harvest and whatever pre-drying of the crop is undertaken. These operations may be carried out in the field or on the farm, by hand or with the help of animals or machines. Depending on the influence of agronomic, economic and social factors, threshing is done in different ways: threshing by hand, with simple tools, threshing with the help of animals or vehicles, mechanical threshing, with simple machines operated manually and Mechanical threshing, with motorized equipment. Whatever the system used, it is very important that threshing be done with care. Otherwise, these operations can cause breakage of the grains or protective husks thus reducing the product's quality and fostering subsequent losses from the action of insects and moulds. Transport of the product from the field to the threshing place, must also be handled with special care, since it can bring about severe losses. Traditional threshing of sorghum (hand-threshing), a worker can obtain 15 to 40 kg of product per hour. For motorized thresher the capacity of threshing depend on the type of machine, the nature and maturity of the grain, the skill of the workers and organization of the work, and they can vary from 100 to 5000 kg/h (FAO, 1990).

In the 1980s, there have also been a number of threshing machines for maize, wheat, rice, sorghum and multiple crops developed in partnership with government research and engineering agencies in Ethiopia Service provision for rice, wheat and maize threshing using locally fabricated threshers is also common in some parts of Ethiopia, as demand for mechanized threshing emerges, although prices are considered to be high due to limited access to threshing technology (Girma and Dawit, 2014). Ownership of threshing machines is more widespread, since threshing is a function that is mechanized earlier than harvesting (Pingali, 2007), and machines are usually much cheaper than tractors or combine harvesters, and can be relatively easily manufactured by local fabricators. In Ethiopia, the number of

government Agricultural Mechanization Service Enterprise (AMSE) hiring stations has reduced to four, with government attempting to privatize the program (World Bank, 2012a).

Relatively inexpensive threshing machines are often fabricated locally and are available on the market in many African countries. Owners can easily hire out threshing services when there is demand for mechanized threshing among other farmers (Diagne *et al.*, 2009). Tractor-mounted maize shellers are manufactured locally in many countries. In Ghana such small machines are an important part of post-harvesting mechanization, which also creates off-season use for tractors and improves the capacity for tractor utilization (Houssou *et al.*, 2014).

Other types of tractor-drawn implements and threshing machines are commonly manufactured in a number of African countries (Tokida, 2011). Fabricators in cities and even rural areas manufacture animal drawn implements such as carts and are often able to repair tractors and tractor-drawn implements to some extent. In Kenya, local manufacturers of equipment such as treadle pumps and hammer mills have become common in Nairobi and have even emerged in smaller towns such as Nakuru (Sims and Kienzie, 2009).

2.2. Agricultural mechanization in Ethiopia.

Looking into the history of agricultural mechanization in Ethiopia, technology development in line of agricultural mechanization and farm implement were not in place till the late 1950s where the Jimma Agricultural Technical School introduced mule-pulled ploughs for tillage practices. This was followed by additional efforts made by Chilalo Agricultural Development Unit (CADU) and Wolaita Agricultural Development Unit (WADU) and Ministry of Agriculture in adapting these ploughs to these specific locations through the development units established at these specific locations (MoA, 2014).

In recognition to the need for agricultural mechanization development, the first higher learning level curriculum on agricultural mechanization program was started in 1958 at the Alemaya College of Agriculture Mechanization and Art (now known as Haramaya University). Later, this was capacitated to train students at First degree level under the Department of Agricultural Engineering. In 1990s Awassa College of Agriculture also opened

the Department of Agricultural Engineering and Mechanization to train students at diploma and degree level. In most cases, these learning institutes were criticized for focusing on large-scale and capital intensive mechanization and ignoring the actual situation on the ground where more than 95% of the farm produce is coming from smallholders operating on less than 2 ha and using traditional implements. In 1976, agricultural mechanization research unit (known then as Agricultural Implements Research and Improvement Center) was hosted in Melkasa Agricultural Research Center. The research unit is still at Melkasa and working and testing different farm implements for tillage, planting, threshing and storage (Abenet *et al.*, 1991).

Gradually, mechanization research continued getting better attention and the agricultural mechanization research directorate was established in 2000 at the Ethiopian Institute of Agricultural Research (EIAR). Following the establishment of mechanization Directorate at EIAR (which is a Federal level research institute), Three Regional Agricultural Research Institutes (Oromia, Amhara and Tigray) also established a parallel structure to own mechanization research programs. The mechanization centers at different regional research institutes have different naming: Bahir Dar Mechanization and Food Science Research Center at Amhara Regional Agricultural Research Institute, Mekele Mechanization and Rural Energy Research at Tigray Agricultural Research Institute, Asella, Bako, Jimma and Fedis Agricultural Mechanization Research Centers are at Oromia Agricultural Research Institute. Though limited in number, there are also private agricultural mechanization centers that contributed to the development of agricultural mechanization in Ethiopia. Selam Vocational Training Centers is a good example in this regard (FACASI, 2011).

Since 2002, there have been three principal development programs set by the Ethiopian Government. These programs are: First, the Sustainable Development and Poverty Reduction Program (SDPRP) designed for three years, 2002/03-2004/05, and have four pillars where Agricultural Development-Led Industrialization (ADLI) was the core one. Second, the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) designed for five years, 2005/06-2009/10, and with eight pillars where agricultural commercialization was a strong pillar. Third, the Growth and Transformation Plan (GTP-1), designed for five years, 2010/11-2014/15, GTP-1 has seven pillars where the major pillar is known for maintaining

agriculture as a major source of economic growth. In all, the three plans/programs mentioned above, enhancing agricultural production and productivity through use of modern agricultural technologies is the fundamental direction the government put. In support of this, the government also allocated more than 10% of its budget to agricultural development. However, like improved seed and fertilizer use, agricultural mechanization and its development plan have not been given due attention in these plans/programs. The existence of such a policy and strategy gap could be a good indication for the slow expansion and development of agricultural mechanization in the country (MoFED, 2006).

During the Emperor's era, one of the strategies designed was to develop and test agricultural technologies using agricultural development units established at different locations and promote these technologies using extension systems. With the support from Swedish International Development Agency (SIDA), the first two development units came to existence in 1960s were the Chilalo Agricultural Development Unit (CADU) and Wolaita Agricultural Development Unit (WADU). In addition to improved seed and chemical fertilizer use, CADU and WADU were also demonstrating agricultural mechanization use. In addition, the government also designed an extension system under the Minimum Package Program (MPP) that mainly focused on enhancing smallholder farmers' access to a package of improved technologies in the regions of WADU and CADU. In 1970s, the Emperor's government developed policies that provide large-scale private commercial farms the privileges to import duty-free farm machinery and parts, access to credit and foreign exchange for buying such equipment with government subsidized loans at 7%, and fuel tax waivers (Cohen, 1987).

When the Dergue came to power, there were handful private farms with better level of mechanization in place. Due to the socialist ideology, the government appropriated private farms with all their properties and put them under state farm. The government kept supporting the state farm through supplying them with better machineries. To maintain the level of agricultural mechanization in large state farms and make them sustainable, under the technical and economic collaboration agreement with the then Union of Soviet Socialist Republic (USSR), the Dergue government established Nazareth Tractor Assembling Plant (NTAP) in 1984. The plant was assembling tractors using tractor parts imported from socialist countries including USSR. The tractors and their implements assembled at NTAP were sold to state

farms and donated to prominent smallholder producer's cooperatives established in cereal based systems. Due to poor management and lack of know-how in machinery operation and maintenance, machineries provided to the producers' cooperatives didn't last long and all cooperatives were abolished starting the mixed-economy proclamation in 1990 and ended with the over-thought of the Dergue government. In terms of agricultural mechanization, like the preceding government, the Dergue government was also favoring capital-intensive and large-scale state farms (Abenet *et al.*, 1991).

The Nazareth Tractor Assembly Plant, established during the Derg regime, is still operating in Ethiopia and is able to assembly roughly 300 tractors per year, which accounted for 46% of tractors entering the Ethiopian market between 2005 and 2010 (World Bank, 2012a).

When the current government came in power, the major contribution of agriculture came from smallholder farmers, the government put a clear agricultural development strategy focusing on enhancing technology generation and use by smallholder farmers to reduce the productivity gap in major crops. However, smallholder agricultural mechanization hasn't got equal attention to other yield improving inputs/technologies like improved seeds and fertilizers (MoA, 2014). In 1992, the tractor assembling plant established during the preceding government was renamed as Adama Agricultural Machinery Industry (AAMI). In 2010, it was transferred to the Metals and Engineering Corporation (METEC) that manages a number of sister industries. AAMI assembles and manufactures tractors, water pumps and various agricultural combines and products. Products from this corporation are used by government, farm unions, and state owned enterprises for agricultural, water irrigation, construction and transportation related projects (www.metec.gov.et). AAMI also trains tractor operators and tractor pulled implements. In 2004 the Council of Ministers issued a regulation for the establishment of AMSE (MoA, 2014).

The enterprise was established to render agricultural mechanization services on rental basis, provide maintenance services on rental basis, sale farm implements and spare parts manufactured domestically or imported, provide transportation services to farm produce and farm inputs, introduce the utilization of modern farm implements by being the transmission belt of modern agricultural technology, provide training and consultation service on a better

ad effective utilization of farm machineries in consideration (FDRE, 2004). In addition to the government owned AMSE, there are also private companies importing agricultural machineries (combine harvesters, large and small tractors, farm implements, etc.) and providing rental services to smallholder farmers particularly in wheat based Arsi and Bale highlands.

2.3. Adoption, Impact and Contributions of Thresher and Combiner

ESSP (2016), in their study explored the scope and determinants of agricultural mechanization by examining data from about 7,000 smallholder households in five regions of the country. This study of agricultural mechanization showed that 9 % of farmers in the Feed the Future regions of Ethiopia used mechanization at some point during the agricultural year 2014/15. They found that mechanized ploughing was most widespread (5%), while mechanized threshing and harvesting was reported by 3 and 2% of households, respectively. They further examined the uptake of different forms of mechanization through a number of associations. The results showed that farm size and rural wages were positively associated with the adoption of mechanization, while remoteness was negatively linked. These findings suggested that as Ethiopia's economy transformed and led to higher rural wages, as well as with further development of its infrastructure, more demand for mechanized agricultural services will likely arise. Having policies that actively assure widespread avail-ability of appropriate mechanized services at low cost seem likely to benefit Ethiopia's agricultural transformation.

In Arsi region of Ethiopia, agricultural mechanization was introduced at the inception of the Chilalo Agricultural Development Unit (CADU) in 1969, but during the Dergue regime was limited to producer cooperatives and state farms. Since the change in government in 1991, small farmers have had access to mechanized technology such as the combine harvester. Farmers in the area used two types of harvesting and threshing methods: manual harvesting (MH) and combine harvesting. On average, 25 and 36 man days and 33 and 51 animal days were required for traditional harvesting and threshing in Asasa and Etheya, respectively. The harvesting and threshing method used by most farmers in the area was combine harvesting. In Asasa and Etheya, 78% and 59% of farmers, respectively, used a combine on at least one of

their fields. Most combines were privately rented (61%) or accessed through government agricultural mechanization services (31%). A third method, used only in a few cases, was manual harvesting and motorized threshing using a stationary thresher. This method was limited to a small number of farmers in the Etheya area, particularly where combine harvesting had no comparative advantage due to unfavorable topography. The average cost of combine harvesting was 11.30 Birr/qt (1 Birr = US\$7), the total cost per quintal differed markedly over the study area. As a result of low yields and high weed infestation, combine harvesting costs were much higher in Asasa (19.53 Birr) than Etheya (15.44 Birr). Also there was a cost increase per quintal of 21% in Asasa and 23% in Etheya for manual harvesting relative to combine harvesting. Besides a reduction in costs, the incremental net benefit of combine harvesting over manual harvesting and threshing was 38% and 16% in Asasa and Etheya, respectively (Hassena *et al.*, 2000).

Paper presented at the Workshop on the Consequences of Small Rice Farm Mechanization Project, December 1-2, 1983, Development Academy of the Philippines (DAP), jointly sponsored by the National Economic and Development Authority (NEDA), Philippine Institute for Development Studies (PIDS), Ministry of Agriculture (MA), and International Rice Research Institute (IRRI) revealed that The use of mechanical threshers in small-scale traditional rice production systems raises several issues. The positive view equates machines with modernization and makes improved mechanical devices a requirement for development. With continuous cropping and increased yields from the use of modern rice varieties and controlled irrigation, the harvest of the first crop closely coincides with land preparation for a second crop. Since labor shortages usually accompany the first harvest, thresher use helps relieve labor bottlenecks which constrain sequential cropping. Threshers reduce labor input from 39 man-hours per ton using traditional techniques to 11 man-hours per ton. Threshers have also evidenced a reduction in quantitative grain losses compared with traditional methods (hand beating) and have increased head rice recovery by 4.7%. Threshing is an important component of the rice production system as it accounts for 42% of the total labor input when using traditional methods (Toquero *et al.*, 1977).

In a rice-rice cropping pattern, threshers can shorten turnaround period by five days (Mennamy and Zandstra, 1978) compared to 23 to 29 days with traditional threshing (Roxas *et al.*, 1977). A long turnaround can result in lower yields and cropping intensity.

Bangladesh is predominately an agricultural country. The contribution to GDP by agriculture is about 21.11% of which crops, fisheries, livestock and forestry account for 11.72, 4.73, 2.90 and 1.76%, respectively (BBS, 2007). The country's food production has increased from 11.0 million tons in 1971 to about 30 million tons in 2007 (Hossain, 2009). The country is, at present, about to achieve self-sufficiency in cereal production. This is due to irrigation development and partial mechanization in other agricultural operations. Contribution of agricultural to GDP over years achieves this target; there is no other better option than to increase productivity per unit of land as well as cropping intensity. Thus, to increase production and cropping intensity, the most important gain was the faster development of agricultural mechanization as well as crop variety development. Replacing the traditional inefficient agricultural tools, efficient mechanized cultivation must be introduced and extended. The good news is that the government has already attributed due importance to agricultural mechanization in the National Agricultural Policy (MoA, 2009).

The Government of Bangladesh was encouraged production and manufacturing of agricultural machinery adaptive to their socio-economic context. Efforts are being continued by the researchers to improve the machine performance. The impact assessment of the wheat threshing machine which was done in Brahmanvita and Jagdal villages confirmed that Wheat production is constrained by the drudgery associated with hand threshing the grain. Hand threshing normally employs two to three laborers for up to 10 days per ton of wheat. Threshing machines are known to be labor saving and are thus likely to save time and remove the drudgery associated with the manual system. However, the impacts of this machine are likely to be different on each of the socio-economic farmer groups. Several locally produced threshing machines are available and all are said to reduce drudgery and cut labor requirements. The largest of these is the "power thresher" that costs Tk39, 000 (USD574). It has a closed drum and an output of 400 kg of wheat grain and chopped straw (suitable as fodder) per hour. The small, open drum thresher requires a small diesel engine to power it. This machine has an output of 150 kg of wheat grain per hour, with the straw being retained

intact. Both threshing machines have the advantage of yielding 10% more and better quality, unbroken grain than is achieved through traditional hand threshing. The wheat threshing machine that was investigated was the small open drum version. It is simple rotating drum applies just enough pressure to the wheat panicles to loosen the grain and release it onto a heap on the ground. The unbroken wheat straw can be used for thatching. This threshing machine is comparatively cheap, costing around Tk4, 000 (USD59), enabling better-off farmers to purchase it directly. A six horse power diesel engine (of the type that is used to drive irrigation pumps) costing Tk9, 600 (USD141) is normally used to power this small threshing machine (Farouk *et al.*, 2007).

2.4. Impact Evaluation Methods

To know the effect of a program on a participating individual, we must compare the observed outcome with the outcome that would have resulted had that individual not participated in the program. However, as stated earlier two outcomes cannot be observed for the same individual. In other words, only the factual outcome can be observed. Thus, the fundamental problem in any social program evaluation is the missing data problem (Ravallion, 2005).

Estimating the impact of a program requires separating its effect from intervening factors which may be correlated with the outcomes, but not caused by the project. This task of “netting out” the effect of the program from other factors is facilitated if control groups are introduced. “Control groups” consist of a comparator group of individuals or households who did not receive the intervention, but have similar characteristics as those receiving the intervention, called the “treatment groups”. Identifying these groups correctly is a key to identifying what would have occurred in the absence of the intervention (Ezemenari *et al.*, 1999). In theory, evaluators could follow three main methods in establishing control and treatment groups: randomization/pure experimental design; non-experimental design and quasi-experimental design. In practice, in the social sciences, the choice of a particular approach depends, among other things, on data availability, cost, and ethics to experiment. In what follows, brief descriptions of the main impact evaluation methods mentioned above (Yibeltal, 2008).

2.4.1. Experimental method

Experimental designs, also known as randomization, are generally considered as the most robust of the evaluation methodologies (Baker, 2000). In a randomized experiment, the treatment and control samples are randomly drawn from the same population. In other words, in a randomized experiment, individuals are randomly placed into two groups, namely, those that receive the program or intervention and those that do not. This allows the researcher to determine program impact by comparing means of outcome variable for the two groups. According to Ezemenari *et al.* (1999), a random assignment of individuals to treatment and non-treatment groups ensures that on average any difference in outcomes of the two groups after the intervention can be attributed to the intervention. The main advantage of a randomized experiment is its ability to avoid problem of selection bias, which arises when participation in the program by individuals is related to their unobservable or unmeasured characteristics (like motivation and confidence), which in turn determine the program outcome. Obviously, randomization must take place before the program begins. Random assignment ensures the two groups are statistically similar (drawn from same distribution) in both observable and unobservable characteristics, thus avoiding program placement and self-selection biases (Bernard *et al.*, 2010).

If implemented appropriately, this design ensures that potential confounders are balanced across program (intervention) and control units and therefore any differences in the outcomes between the two can be attributed to the program. Although experimental designs are considered the optimum approach to estimate project/program impact, in practice, there are several problems. It is not feasible in demand driven programs in which users make their own decisions of whether to use or not to use and about the kind of activities to do in the learning process (Ravillion, 2005; Bernard *et al.*, 2010).

2.4.2. Non-experimental method

A non-experimental approach is used in cases where program placement is intentionally located. For programs that are often setup intentionally, it is common to only have access to a single cross-sectional survey done after the program is introduced (Jalan and Ravillion,

2003). According to Bryson *et al.* (2002), there are two broad categories of non-experimental approach; before and after estimator and cross-sectional estimator. The essential idea of the before and after estimator of an impact evaluation approach is to compare the outcome of interest variable for a group of individuals after participating in a program with outcome of the same variable for the same group or a broadly equivalent group before participating in the program and to view the difference between the two outcomes as the estimate of average treatment effect on the treated. Cross-section estimators use non-participants to derive the counterfactual for participants in which case it becomes quasi-experimental method.

2.4.3. Quasi-experimental method

Quasi-experimental design involves matching program participants with a comparable group of individuals who did not participate in the program. This simulates randomization but need not take place prior to the intervention (Kerr *et al.*, 2000). A quasi-experimental method is the only alternative when neither a baseline survey nor randomizations are feasible options (Jalan and Ravallion, 2003). Quasi-experimental method consists of constructed (matched) control where individuals to whom the intervention is applied are matched with an “equivalent” group from whom the intervention is withheld (Ezemenari *et al.*, 1999). The study used this method as there is no base line data and as the program placement is not random.

2.5. Propensity Score Matching (PSM) Method

The impact of sorghum thresher in reducing expenditure is the difference in households’ mean cost of threshing with the participation and non-participation in the threshing machine. However, households participating in the program cannot be simultaneously observed in two states. A household can either be in the program or outside the program. Thus, the fundamental problem of such an impact evaluation is a missing data problem. Rosenbaum and Rubin (1983) were the first to develop the PSM statistical tool. Propensity score matching as a method to reduce the bias in the estimation of treatment effects with observational data sets. The technique has attracted attention of social program evaluators since the last fifteen years see for *e.g.*, jalan and Ravallion (2003). The present study also used a PSM technique to address its main objectives which was impact of renting-in sorghum threshing machine on

household expenditure in the study area. The PSM technique enables us to extract from the sample of non-participating households a set of matching households that look like the participating households in all relevant pre-participation characteristics. In other words, PSM matches each participant household with a non-participant household that has almost the same likelihood of participating into the threshing machine utilization.

PSM is preferred to the traditional regression method in several ways. Among others, PSM compares outcome for observations, who share similar observable characteristics. Moreover, PSM only compares households lay in the common support and excluded others from the analysis. In this study “treatment” implies participation in the renting-in sorghum thresher and “impact” is meant for the change of house hold expenditure as an outcome indicator. On the other hand, “control” stands for non-participant/non-treated households were used for comparison. According to Caliendo and Kopeinig (2005), there are steps in implementing PSM. These are estimation of the propensity scores, choosing a matching algorithm, checking on common support condition and testing the matching quality.

2.5.1. Procedures of propensity score estimation

The first step in PSM method is to estimate the propensity scores. As described by Rosenbaum and Rubin (1983), matching can be performed conditioning on $P(X)$ alone rather than on X , where $P(X) = \text{Prob}(D=1|X)$ is the probability of participating in the program conditional on X . If outcomes without the intervention are independent of participation given X , then they are also independent of participation given $P(X)$. This reduces a multidimensional matching problem to a single dimensional problem. A logit model is used to estimate propensity scores using a composite of pre-participation characteristics of the sampled households (Rosenbaum and Robin, 1983) and matching is then performed using propensity scores of each observation. According to matching theory (Rosenbaum and Robin, 1983; Bryson *et al.*, 2002; Jalan and Ravallion, 2003), the logit model via which the propensity score is generated should include predictor variables that influence the selection procedure or participation in the program and the outcome of interest.

Several factors guide selection of predictor variables. Many explanatory variables were included as possible to minimize the problem of unobservable characteristics in our evaluation of the impact of renting-in of sorghum thresher. One should also exclude those non-participants for whom the probability of participating is zero.

2.5.2. Matching estimators

There are different matching estimators in theory. Below, only the most commonly applied matching estimators are described. These are: Nearest Neighbor (NN) Matching: it is the most straight forward matching estimator. In NN matching, an individual from a comparison group is chosen as a matching partner for a treated individual that is closest in terms of propensity score (Caliendo and Kopeinig, 2005). NN matching can be done with or without replacement options. In the case of the NN matching with replacement, a comparison (non-participant) individual can be matched to more than one treatment individuals, which would result in increased quality of matches and decreased precision of estimates. On the other hand, in the case of NN matching without replacement, a comparison individual can be used only once. Matching without replacement increases bias but it could improve the precision of the estimates. In cases where the treatment and comparison units are very different, finding a satisfactory match by matching without replacement can be very problematic (Dehejia and Wahba, 2002).

Caliper and Radius Matching: NN matching faces the risk of bad matches, if the closest neighbor is far away. This can be avoided by imposing a tolerance level on the maximum propensity score distance (caliper). Imposing a caliper works in the same direction as allowing for replacement. Bad matches are avoided and hence the matching quality rises. However, if fewer matches can be performed, the variance of the estimates increases. Applying caliper matching means that those individual from the comparison group is chosen as a matching partner for a treated individual that lies within the caliper (‘propensity range’) and is closest in terms of propensity score. As Smith and Todd (2005) note, a possible drawback of caliper matching is that it is difficult to know a priori what choice for the tolerance level is reasonable.

Dehejia and Wahba (2002) suggest a variant of caliper matching which is called radius matching. The basic idea of this variant is to use not only the nearest neighbor within each caliper but all of the comparison members within the caliper. A benefit of this approach is that it uses only as many comparison units as are available within the caliper and therefore allows for usage of extra (fewer) units when good matches are (not) available. Hence, it shares the attractive feature of over sampling mentioned above, but avoids the risk of bad matches.

If the dimension of the neighborhood is set to be very small, it is possible that some treated units are not matched because the neighborhood does not contain a control unit. On the other hand, the smaller the size of the neighborhood the better is the quality of the matches (Becker and Ichino, 2002). One problem in caliper matching is that it is difficult to know a priori what choice for the tolerance level is reasonable.

Kernel Matching(KM): this is another matching method whereby all treated units are matched with a weighted average of all controls with weights which are inversely proportional to the distance between the propensity scores of treated and controls (Becker and Ichino, 2002; Venetoklis, 2004). Kernel weights the contribution of each comparison (non-participant) group member so that more importance is attached to those comparators providing a better match. The difference from caliper matching, however, is that those who are included are weighted according to their proximity with respect to the propensity score. The most common approach is to use the normal distribution (with a mean of zero) as a kernel, where the weight attached to a particular comparator is proportional to the frequency of the distribution for the difference in scores observed (Bryson *et al.*, 2002).

According to Caliendo and Kopeinig (2005) a drawback of this method is that possibly bad matches are used as the estimator includes comparator observations for all treatment observation. Hence, the proper imposition of the common support condition is of major importance for kernel matching method. A practical objection to its use is that it was often not be obvious how to set the tolerance. However, according to Mendola (2007) kernel matching with 0.25 band width is most commonly used.

In other words, it should be clear that there is no 'winner' for all situations and that the choice of a matching estimator crucially depends on the situation at hand. The choice of a specific method depends on the data in question, and in particular on the degree of overlap between the treatment and comparison groups in terms of the propensity score. When there is substantial overlap in the distribution of the propensity score between the comparison and treatment groups, most of the matching algorithms will yield similar results (Dehejia and Wahba, 2002).

2.5.3. Region of common support condition

Imposing a common support condition ensures that any combination of characteristics observed in the treatment group can also be observed among the control group (Bryson *et al.*, 2002). No matches can be formed to estimate the parameters when there is no overlap between the treatment and comparison groups. It also guarantees an individual with observable characteristics to have a positive probability of belonging both to the participants and control group (Rosenbaum and Rubin, 1983).

2.6. Empirical Studies in Ethiopia and Abroad

There have been very few empirical studies found in Ethiopia in the area of agricultural mechanization. Those studies are presented in the following manner. According to ESSP (2016), research note that provided a preview of results from a study of agricultural mechanization in Ethiopia showed that 9 % of farmers in the Feed the Future regions of Ethiopia used mechanization at some point during the agricultural year 2014/15. They found that mechanized threshing and harvesting was reported by 3 and 2 % of households, respectively. They further examined the uptake of different forms of mechanization through a number of associations. The results showed that, farm size and rural wages were positively associated with the adoption of mechanization, while remoteness was negatively linked. Households with educated heads were more likely to use agricultural machines. A suspected, land size was positively associated with the probability of using machines during land preparation, harvesting, and threshing. Interestingly, households with predominantly flat land were more likely to use machines during harvesting and threshing, but less likely during

ploughing. Sorghum farmers were more likely to use machines for ploughing and threshing, but not for harvesting.

For the study undertaken in Arsi Region on wheat harvesting and threshing technologies to assess their profitability compared to that of alternative wheat harvesting technologies, data were collected as of a random sample of 160 farmers from two purposively selected districts, Asasa and Etheya, where harvesting and threshing operations are becoming increasingly mechanized. Logit analysis showed that proximity to a hiring station, topography (accessibility), education level, and wheat area significantly affected farmers' decisions to adopt combine harvesting. The profitability analysis determined that combine harvesting reduced yield losses, costs, and processing time and increased profitability. Financial and economic profitability analyses indicate that combine harvesting is more profitable for the nation than manual harvesting and threshing (Hassena *et al.*, 2000).

A study was conducted to evaluate the impact of the row planting technology specifically teff crop on farm household income in Tahtay Maychew District Tigray Regional State. Both descriptive and econometric data analysis techniques were applied. The analysis was based on primary and secondary data. Household level cross sectional data collected from 300 randomly selected rural households of which 120 of them were participants and the remaining 180 were non-participants. Propensity Score Matching (PSM) and Heckman two stage selection models were used. The results of a propensity score matching showed that the adoption of row planting increased the teff crop income by about 1062.667 Birr per year for NNM, which was significant at 5% probability level, 1077.854 birr per year for SM which was significant at 1% probability level, 1004.172 birr per year for KM which was significant at 1% probability level and 1959.60 birr per year for RM which was significant at 1% probability level, on average compared to the non-adopters. In the first stage of the Heckman two-step procedure, six variables were found to determine participation in row planting technology. After the selectivity bias was controlled by the model in the second stage the inverse Mills ratio (LAMBDA) variables and other three variables were found to have significantly determined household teff crop income (Yonas, 2013).

Mahrouf *et al* (2004) in Sri Lanka, conducted study to evaluate contribution of combine harvesters, on timeliness, harvesting cost, crop yield, farm income and employment in case of paddy crop. The results indicated that the combine harvester ensured rapid harvesting, reduced harvesting costs, minimized post-harvest losses, raised income of farmers and assisted farmers to overcoming labor shortages during peak harvesting period. The machine replaced labor by about 80-85 %, reduced the harvesting costs by Rs.3800 per hectare and increased net return by around Rs.7, 850 per hectare. Field conditions such as crop density, crop maturity, soil moisture condition, weed population, plot size, lodging and operators skills determined the efficiency of harvesting.

Hossain *et al* (2013) in Bangladesh carried out a study at four selected villages, to determine technical and economic feasibility of 4 hp engine driven open drum thresher, 1.0 hp and ½ hp motor driven open drum thresher and identify the better thresher for rural farmers'. The threshing capacity and threshing efficiency of 4 hp engine, 1 hp motor and ½ hp motor driven thresher were found 346.74, 282.46 and 162.44 kg/hr, and 98.77, 99.17, 98.61% respectively. The threshing loss of BRRIdhan30 in the motor and engine driven thresher ranged from 4.32 to 2.34%, which was much lower than the traditional threshing (7%). Labor savings for 1.0 hp motor driven thresher was found highest (53.34%) and was lowest for ½ hp motor driven threshers (39.14%). Similarly, cost savings for 1.0 hp motor driven thresher was more than 4 hp engine driven and ½ hp motor driven threshers. The threshing cost for 1.0 hp motor driven thresher was lowest (TK 396.19 per ton), followed by ½ hp motor driven, and 4 hp engine driven thresher. Threshing cost was an important issue in the selection of thresher. On the basis of lower threshing cost, 1.0 hp motor driven thresher was a better option for the farmers. Benefit cost ratio was highest for 1.0 hp motor driven thresher (1.70) followed by ½ hp motor and 4 hp engine driven thresher. Considering economic suitability of threshing operation, 1.0 hp motor driven thresher appeared to be a better option for the farmers.

3. REASERCH METHODOLOGY

3.1. Description of the Study Area

The study was conducted in Oromia National Regional State, East Hararghe Zone, Haramaya district at Fendisha lencha and Gende haqa qebeles. Eastern Hararghe zone is one of the 18 zones of the Oromia National Regional State. It is located in the Eastern part of the country. It is divided into 19 districts. Harar is the capital town of the zone and is located at the distance of 525 *km* from Addis Ababa.

Likewise Haramaya district is located in the central part of Eastern Hararghe zone. The total area of district was about 55,555 ha (HDARDO, 2014). The district has total of 34 PAs having 33 PA's of rural and 1 rural town. Haramaya district is located at distance of 19 Km from Harar town. The 2007 national census reported the total populations for this district as 271,018, of which 18.46% were urban and 81.54% were rural. The rural people in Haramaya district are of Oromo in nationality and Muslim in religion. Concerning household size, a rural household had an average size of seven while the urban one had six individuals (AWOARD, 2011).

The livelihood of the farmers is based on agriculture. The farmers in the area practice mixed type farming. The district is known for its bimodal rainfall patterns *i.e.*, there are two cropping seasons, summer and belg seasons. Land use pattern of the district shows that cultivated land, grazing land, forest, bush-shrubs and chat *etc.* Sorghum and maize are the most important cereal grain produced in the area and consumed by rural community. The major crops grown in the district are cereals: - sorghum, maize, wheat, barley and millet, pulses:-bean and pea, and vegetables: - potato, sweet potato, tomato, onion, carrot, root beat and cabbage and fruits like banana and papaya are produced in the district.

However, Sorghum dominates both in terms of area coverage and in total quantity produced. It covered an area of 13,017.5 hectares with 342,442 quintals of production and 26 quintals per hectare productivity (HDARDO, 2014).



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

Source: Tesfaye, 2003

Haramaya is situated in the semi-arid tropical belt of Eastern Ethiopia and characterized by a sub-humid climate with an average annual rainfall of about 790 mm, annual mean temperatures of 17°C with mean minimum and maximum temperatures of 9.4 and 24°C, respectively. The area experiences biannual type of rainfall classified as short and long rainy seasons. The short rainy season usually occurs from end of February to mid-May and the long rainy seasons occur from July to end of September (Tesfaye, 2003). Its altitude ranges from 1600 to 2100 meters above sea level.

3.2. Type, Sources of Data and Method of Data Collection

Both primary and secondary data sources were used for this study. The required primary data were collected from randomly selected sample households using structured questionnaire. The enumerators were employed on the basis of their educational background and their ability of the local language. Two days training was given to the enumerators about method of data collection and the contents of the questionnaire. After pre-tested the questionnaire,

modifications were made based on the feedback from the pre-test. Data collection was started December 2015 and ended December 30 2015.

For Primary data collection sampled households were asked to answer a series of questions included in the survey questionnaire. The survey questionnaire was prepared to bring out information on a variety of topics including resource endowment, perception of farmers on sorghum threshing machine, agricultural extension services, access to the technology, and demographic characteristics of the respondents.

Secondary data that could supplement the primary data were collected from published and unpublished documents obtained from, Eastern Hararghe zone, Ministry of Agricultural and Rural Development, Fedis agricultural research centers, Melkasa Agricultural research Center and websites. .

3.3. Sampling Techniques and Sample size

In order to select the representative sample, first of all out of the 34 rural kebeles of Haramaya district, two kebeles were selected purposively where there is more number of thresher operating. Sample size of respondent from each selected kebeles was determined using probability proportional to size method. That is, from the total households of 1530 in the two kebeles 762 (49.81%) from Fendisha Lencha and 768 (50.19%) From Haqa kebele were selected.

To select sample respondents from the two kebeles, first the household heads in the two kebeles were identified and stratified in to two strata: Sorghum threshing machine user and non-user. Then the sample from each stratum was selected randomly using simple random sampling technique through random number generator. Thus, from 180 sample households 90 households from Fendisha Lencha and 90 households from Haqa kebeles were selected. In other words, 180 households (90 users and 90 non-users) were selected randomly from two kebeles. Total sample size for each PA was categorized as sorghum thresher user and non-user of thresher for both the sampled kebele see Table 1.

Table.1. Population and sample size by peasant associations

Sample peasant association	Total households	Sample households	Sorghum thresher	
			Users	Non-users
Fendisha Lencha	762	90	45	45
Haqa	768	90	45	45
Total	1530	180	90	90

Source: The district agricultural office; and own computation results

The size of sample was determined using following formula of Kothari (2004).

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

Where, n = sample size

N = total households number

e = the acceptable sampling error.

P = population reliability (or frequency estimated for a sample of size n), where p is 0.5 which is taken for all developing countries population and $p + q = 1$

$Z = \alpha / 2$: normal reduced variable at 0.05 level of significance z is 1.96

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq} = \frac{1.96^2 * 0.5 * 0.5 * 1530}{0.07^2(1530-1) + 1.96^2 * 0.5 * 0.5} = \frac{1469.41}{7.49 + 0.96} = 180$$

Thus, this study was based on 180 sample households.

3.4. Method of Data Analysis

Based on the objectives of study, both descriptive statistics and econometric models were employed to analyze both qualitative and quantitative data. From econometric model, logit

model was applied to analyze the factors affecting use of thresher and Propensity Score Matching method (PSM) for impact evaluation.

3.4.1. Descriptive statistics

By applying descriptive statistics, one can compare and contrast different categories of sample units with respect to the desired characteristics. It was used to explain the different socio-economic, institutional and other characteristics of the sample households. These include mean, percentage, standard deviation, ratio and frequency of occurrence for the sorghum thresher user and non-user farmers. The statistical significance of the variables was tested for both dummy and continuous variables using chi-square and t-tests, respectively

3.4.2. Econometrics analysis

3.4.2.1. Econometric analysis for factors affecting sorghum thresher utilization

The logit and probit are the two most commonly used models for analyzing the effects of various factors that affect the probability of adoption of a given technology. These models can also provide the predicted probability of adoption. Both models usually yield similar results. However, the logit model is simpler in estimation than probit model as indicated in Aldrich and Nelson (1984). Hence, the logit model was used in this study to identify the determinant of using a thresher. Following Liao (1994), Gujarati (2003) and Aldrich and Nelson (1984), the logistic distribution function for the utilization of thresher for sorghum crop was specified as:

$$p_i = \frac{1}{1 + e^{-Z_i}} = \frac{e^{Z_i}}{1 + e^{Z_i}} \quad (2)$$

Where, p_i = is the probability of using the thresher for sorghum threshing for the i^{th} farmer and its value ranged from 0-1.

e^{Z_i} = stands for the irrational number e to the power of Z_i .

Z_i = a function of n-explanatory variables which was expressed as:

$$Z_i = \alpha_0 + \alpha_1 i_1 + \alpha_2 i_2 + \dots + \alpha_n i_n \quad (3)$$

Where, $i_1, i_2, \dots, i_n$ are explanatory variables.

α_0 - is the intercept, $\alpha_1, \alpha_2, \dots, \alpha_n$ are the logit parameters (slopes) of the equation in the model.

The slopes tell how the log-odds ratio in favor of using the machine changes as an independent variable changes. The unobservable stimulus index Z_i assumes any values and is actually a linear function of factors influencing adoption decision of thresher for threshing sorghum. It is easy to verify that Z_i ranges from $-\infty$ to ∞ , P_i ranges between 0 and 1 and that P_i is non-linear related to the explanatory variables, satisfying following two requirements:

As i_i increases P_i increases but remains between 0 and 1 interval; and The relationship between P_i and i_i is non-linear, i.e., one which approaches zero at slower and slower rates as i_i gets small and approaches one at slower and slower rate as X_i gets very large. But it seems that in satisfying these requirements, an estimation problem has been created because P_i is not only non-linear in i_i but also in the α 's as well, as can be seen clearly below.

$$p_i = \frac{1}{1 + e^{-\alpha_0 - \alpha_1 i_1 - \alpha_2 i_2 - \dots - \alpha_n i_n}} \quad (4)$$

This means the familiar OLS procedure cannot be used to estimate the parameters. But this problem is more apparent than real because this equation is intrinsically linear. If P_i is the probability of adopting a given sorghum thresher then $(1-P_i)$, the probability of not adopting, can be written as:

$$1 - p_i = \frac{1}{1 + e^{Z_i}} \quad (5)$$

Thus, the odds ratio can be written as:

$$\frac{p_i}{1-p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^{z_i} \quad (6)$$

And so $\frac{p_i}{1-p_i}$ is simply the odds ratio in favor of adopting sorghum thresher. It is the ratio of

the probability that the farmer would use the machine to the probability that he would not use it. Finally, taking the natural log of equation 5, the log of odds ratio can be written as:

$$L_i = \ln\left(\frac{p_i}{1-p_i}\right) = \ln\left(e^{\beta_0 + \sum_{i=1}^n \beta_i x_i}\right) = Z_i = \beta_0 + \sum_{i=1}^n \beta_i x_i \quad (7)$$

Where, L_i is log of the odds ratio in favor of using sorghum thresher, which is not only linear in x_i , but also linear in the parameters. Thus, if the stochastic disturbance term,

(U_i), is introduced, the logit model becomes:

$$Z_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_n x_{in} + U_i \quad (8)$$

This model can be estimated using the iterative maximum likelihood (ML) estimation procedure. In reality, the significant explanatory variables do not have the same level of impact on the adoption decision of farmers. The relative effect of a given quantitative explanatory variable on the adoption decision is measured by examining adoption elasticities, defined as the percentage change in probabilities that would result from a percentage change in the value of these variables. To calculate the elasticity, one need to select a variable of interest, compute the associated P_i , vary the X_i of interest by some small amount and re-compute the P_i , and then measure the rate of change as $\frac{dx_i}{dp_i}$ where $\frac{dx_i}{dx_i}$ and $\frac{dp_i}{dp_i}$ stand for Percentage changes in the continuous explanatory variable (x_i) and in the associated probability level(p_i), respectively. When $\frac{dx_i}{dx_i}$ is very small, this rate of change is simply the derivative of p_i with respect to x_i and is expressed as follows (Aldrich and Nelson, 1984).

$$\frac{dP_i}{dz_i} = \frac{e^{z_i}}{(1 + e^{z_i})^2} \quad P_i = \frac{e^{z_i}}{1 + e^{z_i}} \quad (9)$$

The impact of each significant qualitative explanatory variable on the probability of adoption is calculated by keeping the continuous variables at their mean values and the dummy variables at their most frequent values zero or one.

3.4.2.2. Parameter estimation

In linear regression, Ordinary Least Square estimation method (OLS) is used to estimate the parameters of the model. That is, selecting regression coefficients that result in the smallest sum of squared differences between the observed and the predicted values of the dependent variables. Under the assumptions of linear regression, the method of least squares yields estimators with a number of desirable statistical properties. Unfortunately, when the method of least squares is applied to a model with a dichotomous outcome, the estimators no longer have these same properties (Hosmer and Lemeshow, 1989; Gujarati, 2003).

Since the method of OLS does not make any assumptions about the probabilistic nature of the disturbance term (U_i), in logistic regression the parameters of the model are estimated using the ML method (Maddala, 1989; Gujarati, 2003). Due to the non-linearity of the logistic regression model, an iterative algorithm is necessary for parameter estimation. Maddala (1989) pointed out that the method of ML is a very general method of estimation that is applicable in large varieties of problems. The ML method of estimation suggests choosing as estimates the values of the parameters that maximize the likelihood function. In many cases it is convenient to maximize the logarithm of the likelihood function rather than the likelihood function and the same results are obtained (Maddala, 1989). Mostly this method is preferred when large sample size is used. Therefore, this method was employed in the present study.

Multicollinearity refers to the existence of more than one exact linear relationship, and collinearity refers to the existence of a single linear relationship. But this distinction is rarely maintained in practice, and multicollinearity refers to both cases (Gujarati, 2003). Before taking the selected variables into the logit model, it is necessary to check for the existence of

multicollinearity among the continuous variables and verify the associations among discrete variables. The reason for this is that the existence of multicollinearity was affecting seriously the parameter estimates. If multicollinearity turns out to be significant, the simultaneous presence of the two variables was attenuate or reinforces the individual effects of these variables. In short, the coefficients of the interaction of the variables indicate whether or not one of the two associated variables should be eliminated from model analysis (Kothari, 1990).

In this study a Variance Inflation Factors ($VIF(i_j)$) technique was employed to detect the problem of multicollinearity for continuous variables (Gujarati, 2004). Each selected continuous explanatory variable (i_j) was regressed on all the other continuous explanatory variables, the coefficients of multiple determination (R_i^2) being constructed in each case. If an appropriate linear relationship exists among the explanatory variables, then this should show up as a large value for R_i^2 in at least one of the test regressions. A popular measure of multicollinearity associated with the ($VIF(i_j)$) is defined as:

$$VIF(i_j) = \frac{1}{1 - R_i^2} \quad (10)$$

Where R_i^2 is the coefficient of multiple determinations when the variable i_j is regressed on the other explanatory variables. A rise in the value of R_i^2 that is an increase in the degree of multicollinearity, does indeed lead to an increase in the variances and the standard errors of the OLS estimators. A VIF value greater than 10 (this happens if R_i^2 exceeds 0.90) is used as a signal for the strong multicollinearity (Gujarati, 2003).

Similarly, there may be also interaction between two qualitative variables, which can lead to the problem of multicollinearity or association. To detect this problem, coefficients of contingency was computed from the survey data. According to Healy (1984), contingency coefficient is a chi-square based measure of association where a value 0.75 or above indicates a stronger relationship. The contingency coefficient is computed as follows:

$$C = \sqrt{\frac{\chi^2_i}{n + \chi^2_i}} \quad (11)$$

Where, C = coefficient of contingency, n = total sample size and χ^2_i = a chi-square value which is estimated as using the following formula.

$$\chi^2_i = \sum_{i=1}^n \frac{(O - E)^2}{E} \quad (12)$$

Where, O = the observed frequency, E = the expected frequency, which is calculated as:

$$E = \frac{\text{Row total} \times \text{Column}}{\text{Grand total}} \quad (13)$$

Where n = number of cells in the table

3.4.2.3. Testing hypotheses about the coefficients

Separate tests of the null hypothesis that individual coefficients are zero can be computed using t-test of the multiple linear regression models (Gujarati, 2003). This test can be used to see the statistical significance of each coefficient. An overall test of the null hypothesis that all the parameters associated with the explanatory variables in these models are equal to zero is an F-test based on the OLS estimation procedure.

In logit and other probability models, the most commonly used test is the likelihood ratio statistic, which approximately follows the chi-square (χ^2) distribution (Liao, 1994). In ML estimation method, a log likelihood ratio test replaces the value of F-test of OLS regression models to evaluate the significance of all or a sub-set of coefficients (Aldrich and Nelson, 1984).

The chi-square tests the null hypothesis that the coefficients for all terms in the model except constant are zero. The log likelihood ratio statistic follows a chi-square distribution with k degrees of freedom (where k is the number of parameters in the equations less the constant) and is calculated as the difference between -2 times log likelihood for the model with only a constant and -2 times log likelihood for the current model: $\chi^2 = -2 (\ln L_0 - \ln L_{\max})$.

Where, L_0 is the value of the likelihood function for the constant only and $L_{\max}$ is the value of the likelihood function when all or a sub-set of independent variables are included in the model (Maddala, 1989).

3.4.3. Propensity Scores Matching (PSM)

It is a tool that creates a comparison group with the treatment group based on factors that influenced people's propensity to participate in the program. It allows finding a comparison group from a sample of non-participants closest to the treatment group in terms of observable characteristics so that both groups are matched on the basis of the propensity score, which is a predicted probability of participation given observed characteristics (Ravallion, 2009). This propensity value is estimated based on a statistical model, *e.g.*, logit or probit model, and thereby estimate the average treatment effect of the outcome difference (*e.g.* income, assets, livestock density, landholding sizes, *etc*) between the two groups using nearest-neighbor, caliper, stratification and kernel matching (Khandker *et al.*, 2009). PSM doesn't require randomization or baseline (pre-intervention) data. It is useful when there are many potential characteristics to match between program participants and non-participants. It is more robust compared to others. However, it requires a large sample size and good quality data. It may not be able to control all pre-existing difference between the two groups (Pufahl and Weiss, 2009).

One important concern that should be taken care of while doing PSM is balancing test. While differences in covariates are expected before matching, these should be avoided after matching. The primary purpose of the PSM is that it serves as a balancing method for covariates between the two groups that participants and non-participants. Consequently, the idea behind balancing tests is to check whether the propensity score is adequately balanced. In

other words, a balancing test seeks to examine if at each value of the propensity score, a given characteristic has the same distribution for the treatment and comparison groups. The propensity scores themselves serve only as devices to balance the observed distribution of covariates between the treated and comparison groups. The success of propensity score estimation is therefore assessed by the resultant balance rather than by the fit of the models used to create the estimated propensity scores (Lee, 2006).

Finally, using predicted probabilities of participation in the participation program (*i.e.* propensity score) match pairs were constructed using alternative methods of matching estimators. Then the impact estimation is the difference between simple mean of outcome variable of interest for participant and non-participant households.

The impact of renting-in service of sorghum thresher on household threshing cost was analyzed. Finding the match for sorghum thresher user household based on a vector of characteristics is equivalent to finding the match based on the probability of participating in renting service, conditional on the vector of farm household characteristics, *i.e.*, $P(i_i) = \Pr(I_i = 1 | i_i)$. Thus the problem reduces to matching the thresher users and non-user's households along their conditional probability of access to the renting service project, a scalar variable that can be estimated from an empirical model such as a logit or probit model. In the present case, the logit regression model was used to derive the propensity scores. The propensity score for every sampled participant and non-participant was computed. The specific step that was followed is given as follows: first select relevant variables influencing the participation of farm households in using renting service and use the estimated thresher utilization model through using logistic regression. Then, derive the predicted probability of utilization of sorghum thresher renting-in service (propensity scores) for machine users and non-users households.

For any machine user household, the non-user household was found with closest propensity score as the match. To accomplish the match, the use of the nearest neighbor (equal weights version) and kernel matching estimators was made. The nearest neighbor method simply identified for each household the closest twin in the opposite machine access status. It then

computed an estimated of the sorghum threshing renting-in service effect as the average difference in household expenditure between each pair of matched households. Thus the mean impact of renting-in service thresher on household expenditure (net decrease in threshing cost) was given by:

$$\Delta_i = \frac{\sum_{j=1}^P Y_{ij1} - \sum_{i=1}^{NP} Y_{ij0}}{P} \quad (14)$$

Where Y_{ij1} is cost of rented-in threshing machine users household j , Y_{ij0} is the cost of manual threshing of the i^{th} non-users household matched to the j^{th} machine users household, P is the total number of users and NP is the total number of non-users. The kernel-based matching estimator is more flexible than the former with respect to the specification of the propensity score. It follows the same steps as the nearest neighbor method, but the matched household was identified as the weighted average of all households in the opposite category within a certain propensity score distance, with weights inversely proportional to the distance.

3.4.4. Sensitivity Analysis

The estimation of treatment effects with matching estimators was based on the CIA that was selected on observable characteristics. However, if there are unobserved variables which affect assignment into treatment and the outcome variable simultaneously, a 'hidden bias' might arise. It should be clear that matching estimators are not robust against this 'hidden bias'. Since it is not possible to estimate the magnitude of selection bias with non-experimental data, we address this problem with the bounding approach proposed by Rosenbaum (2002). The basic question to be answered is, if inference about treatment effects may be altered by unobserved factors. In other words, we want to determine how strongly an unmeasured variable must influence the selection process in order to undermine the implications of matching analysis. Previous applications of this approach can be found in Aakvik (2001), Diprete and Gangl (2005) or Caliendo, Hujer, and Thomsen (2005).

3.5. Definition of variables in the model and the hypothesis

The Dependent variable: In this study, renting-in sorghum threshing machine users and non-users was treated as dependent variable. To analyze factor affecting renting-in service of thresher for sorghum threshing, the dependent variable was dichotomous and represented the observed thresher usage. It was represented in the model as sorghum thresher user = 1 for a household that use renting-in service and non-user = 0 for a household that did not use sorghum thresher renting-in service for threshing sorghum.

Outcome variables: Expenditure on renting-in thresher for sorghum threshing per ton. It includes, machine renting cost and labor cost incurred for feeding the machine and gathering the harvest. For machine non-user's expenditure on manual threshing per ton. It comprises labor cost, food items cost and material cost. Sorghum threshing renting-in service users households are expected to reduce cost of threshing than non-user households. Period of production year considered was 2015. The major independent variables that were expected to influence the use of thresher are explained below:

Age of the household head (FAGE): In Ethiopia, household head is the decision maker for farm activities. Age is a continuous variable and measured in years. It is one of the factors that determine decision making of a person. Advanced aged household heads are more reluctant to accept new technology than younger household heads (Getaneh, 2011). Similarly In this study also, it was hypothesized that farmer's with old age is negatively related with utilization of sorghum threshing machine.

Education level of the household head (EDULEVEL): It refers to the number of years of formal education completed by the household head. Education could increase the farmers' ability to obtain process and use information. Better educated households used mechanical threshing method than traditional (Vishwanatha, 2005). On his study result of socio-economic characteristics of the sample respondents showed. Thus, education is increase the probability of farmers 'adoption of new technologies. In this study, it was hypothesized that a farmer's educational level to be positively related with utilization of sorghum threshing machine.

Number of extension contact (NEXECONTA): This refers to the number of contacts with extension agents that the sample farmer made in a year. In fact agricultural extension is an important source of information, knowledge and advice to smallholder farmers in Ethiopia. Subsequent provision of technical supports (extension services) increased the farmers' knowledge, allocation skills and awareness towards new innovations (Berhanu, 2002). Therefore, extension contact was expected to influence farmers' decision to utilize threshing machine positively.

Family size (FAMSIZE): This refers to the total number of members in a family. Large family size has sufficient labor required to manually harvest wheat (Hassena *et al.*, 2000). Similarly a larger family size has enough labor for manually threshing sorghum. Thus; a large family size would be expected to decrease the probability that a farmer used a Sorghum thresher.

Social Status of the household head (SSHH): The farmer's experience in community leadership is positively associated with the adoption of new technologies because of his/her timely access to useful information or capability to interpret and use the available information related to a given technology (Withana *et al.*, 2004). The variable was given the value 1 if the respondent assumes social leadership and 0 otherwise. Farmers, who participated in community leader ship, were believed to be positively related with the adoption of sorghum thresher.

Sex of the household head (SEXHH): This is measured as a dummy variable taking the value of 1 for male headed household and 0 otherwise. Male headed households may have better labor force than female headed households and male headed households are economically richer than the female headed households who face labor shortage and are poor (Mamo, 2002). It is therefore hypothesized that sex of the farmer being male has a positive influence on the utilization of sorghum thresher.

Off/non-farm activities (OFNOFACT): This is treated as a dummy variable and was measured as 1 if the household was involved in off/non-farm activities and, 0 otherwise. This is because farmers may allocate more of their time to regular farm activities and thus may use

their free time for off/non-farm activities. On the other hand, incomes from off/non-farm activities may be used as extra cash to buy agricultural inputs and also be a supplement for home use. Additional income increases farmers' financial capacity and is expected to increase the probability of investing in new technologies (Mesfin, 2005). Thus, farmers who are participating in off/non-farm activities were expected to adopt sorghum threshing machine.

Distance from market centre (MARKETDI): Research results reported by Kidane (2001), Endrias (2003) and Mesfin (2005) indicated that there was negative relationship between market distance and adoption of new technologies. Hence, distance (in Kms) from the farm to market place was expected to be negatively related to threshing machine utilization.

Livestock holding of the household head (LSTOCHOL): This refers to the total number of livestock measured in tropical livestock unit (TLU). Livestock is used as a proxy for wealth so that, the household can purchase and have an opportunity to utilize new technology. Previous research results reported by Yonas (2013) and Mesfin (2005) confirmed that livestock holding has positive influence on technology adoption. Therefore, in this study it was hypothesized that higher TLU to have positive influence on the use of sorghum thresher. .

Total cultivated land (CULTLAND): It is the total land devoted to crop production including that owned, rented in, contracted in and obtained through gift, and measured in hectare. It is an important input to agricultural production affecting farm output. As far as pattern of land holding is concerned, the average size of land holding of traditional threshing sample respondent was less than mechanical threshing sample respondents (Vishwanatha,2005).In this study also, it was imagined that total cultivated land has a positive relation with the decision to use sorghum thresher.

Farmer's access to the technology (TECHACCE): The accessibility of combine hiring services is measured in terms of a farmer's nearness to towns and topography of the area, and was grouped as accessible and non-accessible (Hassena *et al.*, 2000). The variable was given the value 1 if the respondent accessible for renting in service and 0 otherwise. Similarly, it was hypothesized that the use of threshing machine services was increased with nearness to thresher hiring stations and with terrain that was conducive to thresher.

Perception of the farmer (FPERSTM): It is a dummy variable which takes a value 1 for those who have better perception about the importance of renting-in sorghum threshing machine service and 0 otherwise. The perception of farmers about the water problem was expected to have a positive impact on farmers' willingness to pay for it (Mamo, 2002; Tiwari, 2005 and Takele, 2008). Similarly, in this study it was hypothesized that better perception about the importance of sorghum thresher renting-in service would have a positive influence on the use of sorghum thresher.

4. RESULTS AND DISCUSSION

This chapter has been divided into three sections. In section one, socio-economic characteristics of sample households have been presented and discussed. Section two presented the results and discussions of determinant factors that affect the participation of sample households for renting-in services of thresher for threshing of sorghum. In section three presented the results related to impact of renting-in service on threshing cost of sorghum and pertaining to propensity score matching are discussed. The results and discussion with respect to all the three sections mentioned above, are presented and discussed as follows.

4.1. Socio-economic Characteristics of Sample Households

To describe the sample households included in this study both discrete and continuous variables were used. First discrete variables are discussed and then continuous variable continued.

Sex of the household head: Female headed households were 11.67% whereas male headed were 88.33%. From renting-in service users, 7% of households were female headed households while, the rest households were male headed. Within non-users households, female headed and male headed were 17% and 83% respectively. The percentage of female renting-in machine users was less than non-renting users. Out of 88% male headed households, 47% were renting-in machine users and 41% were non-users. The result showed that there was a significant difference in the sex of the sampled household heads for renting-in machine users and non-users households at 10 % probability level (Table 2).

Social status of the households: Renting-in machine service user participant households were 37.78% and non-participants 62.22% from non-renting-in machine users, 11.11% were participants whereas, non-participants were 88.89%. This variable was statistically significant at 1% probability level for renting-in service users (Table 2).

Off/non-farm activities: the result regarding this variable indicated that 7% of renting-in service users households were employed in off/non-farm activities, and the remaining 93% were un-employed. Only 2% of non-users of renting-in services households were employed in off/non-farm activities. The chi-square (χ^2) result showed that off/non-farm activities were not statistically significant for both renting-in service users and non-users (Table 2).

Farmer's access to technology: About 54% of renting-in service user households had access to farm technology while 46% had no access. From non-renting-in service users 16% of households had access to farm technology and 74% had no access. The chi-square (χ^2) result showed that there were significant differences in using rental services at less than 1% probability level of significant (Table 2).

Perception of the farmer: Almost the entire Renting-in service user's households perceive that sorghum threshing renting-in service is a very important technology and 86% of the non-user households responded that renting-in service is very important, and 14% of them felt that it is not important. There is a statistically significant difference in perception about the importance of the machine between user and non-user households at 1% probability level (Table 2).

Table.2. Socio-economic characteristics of sample households (Discrete variables)

Variables	Categories	Renting-in service				P-value	χ^2 -value
		Users		Non-users			
		HH=90		HH=90			
		Number	%	Number	%		
Sex of the house hold head	Male	84	93.33	75	82.22	0.061	4.495*
	Female	6	6.6	15	16.67		
Social status of the households	Participant	34	37.78	10	11.11	0.000	18.090***
	Non-participant	56	62.22	80	88.89		
Off/non-farm activities	Employed	6	6.66	2	2.22	0.278	2.186
	Un-employed	84	93.33	88	97.77		
Farmer's access to technology	Access to tech.	49	54.44	16	17.77	0.000	27.164***
	No access to tech.	41	45.55	74	82.22		
Perception of farmer	Positive perception	89	98.89	77	85.56	0.001	13.071***
	Negative perception	1	1.11	13	14.44		

Source: own survey, 2016

***, ** and * indicate significant at 1%, 5% and 10% probability levels, respectively.

The descriptive analysis results for continuous variables were depicted in table.3. The sample households were based on sorghum threshing machine renting-in service users and non-users. The average education level of renting-in service users and non-users shows that average schooling years of renting-in service users and non-users were 4.74 and 1.84 respectively. The overall average education levels of the household were 3.29 years. The mean difference between renting-in service users and non-users were statistically significant at 1% probability level (Table 3).

The average cultivated land size of all sample respondents was 0.77 ha. On an average, participant households had 0.86 ha while non-participants had 0.68 ha. There were significant differences in their cultivated land size. The result showed that mean difference between cultivated land of service users and non-users was found to be significant at 1% significant level (Table 3).

The average livestock holding of household was 3.79 in TLU. On average, service user's household had 4.41 while, that of non-users 3.18. Users had more livestock compared to non-users. The result further revealed that, the mean difference between users and non-user's household was significant at less than 1% level of significance. So, renting-in service users households have the capacity to purchase and use the technology (Table 3).

As it can be seen from table 3 average number of extension contact for renting-in service users were 3.49 that of non-users is 1.86. The difference in means between renting-in service users and non-users were statistically significant at less than 1% probability level.

Table.3.Socio-economic characteristics of sample household (Continuous variables)

Variables	Total Sample (n=180)		Renting-in service Users (n=90)		Non-users of renting-in service (n=90)		Difference in means	Std. deviation	p-value	t- value
	Mean	SD	Mean	SD	Mean	SD		SD		
Farmer's age	40.883	7.435	40.467	8.076	41.3	6.75	-0.833	1.11	0.454	-0.751
Education level	3.294	3.382	4.744	3.407	1.844	2.673	2.900	0.456	0.00	6.353***
Family size	6.74	2.014	6.67	2.162	6.82	1.864	-0.156	0.301	0.606	-0.517
Farming experience	23.19	7.899	22.76	8.725	23.62	6.999	-0.867	1.179	0.463	-0.735
Total cultivated land	0.772	0.309	0.855	0.345	0.687	0.243	0.167	0.045	0.00	3.747***
Livestock holding	3.791	1.854	4.405	1.932	3.177	1.555	1.229	0.261	0.00	4.700***
Market distance	5.675	1.745	5.811	1.717	5.539	1.771	0.272	0.26	0.296	1.047
Number of extension contact	2.67	1.775	3.49	1.256	1.86	1.845	1.633	0.235	0.00	6.94***

Source: own survey, 2016

***and * means significant at the 1%, and 10% probability levels, respectively.

Table.4 presents descriptive statistics results of sample households based on measure of cost of threshing. Households who were using renting-in service and non-users were evaluated on their costs of threshing. The survey results showed that on average renting-in service user households' had shown decrease in their threshing cost of sorghum by 924.01 birr per ton whereas, households who were non-user of renting service that is who were using traditional method threshing system incurred threshing cost of 924 birr per ton. This means, households that participated in renting-in service of threshing machine were better off in reducing their sorghum threshing expenditure than that of non-participant. The result of the study showed that the mean difference between machine users and non-user's households were statistically significant at less than 1% probability level on reduction of threshing cost.

Table .4.Sorghum threshing cost (Birr per ton) through use of thresher and traditional method

Variable	All sample households		Participant		Non-participant		Mean Difference	Std. Deviation	p-value	t-value
	HH=180		HH=90		HH=90					
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Sorghum threshing cost birr/ton	796.54	502.04	334.54	66.67	1258.55	266	924.01	28.91	0.000	31.963***

Source: own survey, 2016

***, shows significant at 1%, probability level

4.2. Econometric Model Results

Using econometric model determinants for participation of renting-in services of thresher were identified. Prior to the estimation of the model parameters, it is important to look into the problem of multicollinearity among the explanatory variables. Variance inflation factor (VIF) was used to check multicollinearity problem among the explanatory variables whereas, contingency coefficient was used for dummy variables. Based on check results of VIF; one explanatory variable namely farming experience was dropped from the model which had multicollinearity were and the function was re-run and problem of multicollinearity was removed (see appendix 4).

Similarly, the test result of contingency coefficient revealed that there was no serious association between the hypothesized discrete variables, since the respective coefficients were less than 0.75 (see appendix 9). In the same way, heteroscedasticity was tested by using Breusch-Pagan/Cook-Weisberg test. This test resulted in the rejection of the existence of heteroscedasticity hypothesis as ($p = 0.198$) and there was no need to make the standard error robust (see appendix 6).

Table.5. Logistic regression results for determinants of renting-in thresher service.

Variables	Coef.	Odds Ratio	Std. Err.	P> z	z
Age	- 0.053	0.949	0.050	0.319	-1.00
Education	0.276***	1.318	0.117	0.002	3.09
Family size	-0.180	0.836	0.160	0.347	-0.94
Social status	1.591**	4.910	3.302	0.018	2.37
Sex	1.139	3.123	2.841	0.211	1.25
Off/non-farm	-0.173	0.841	1.111	0.896	- 0.13
Market distance	0.047	1.048	0.153	0.750	0.32
Cultivated land	3.495***	32.966	43.689	0.008	2.64
Technology	2.792***	16.308	9.238	0.000	4.93
Number of contact	0.718***	2.051	0.365	0.000	4.04
Perception	2.564*	12.992	19.671	0.090	1.69
Constant	-7.284	0.0007	0.0019	0.008	-2.66
Number of obs = 180 LR $\chi^2(11)$ = 128.11 Prob> χ^2 = 0.000					
Log likelihood = -60.710 Pseudo R ² = 0.5134					

Source: own survey, 2016

***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively.

The results of estimation of the logit regression 11 independent variables were hypothesized to influence the use of renting-in service of thresher for threshing sorghum see Table.5. Out of these 11 variables, 6 variables were significant at various probability levels. 4 of them were found to be statistically significant at 1%, 1 significant at 5 % and 1 at 10 % probability level. However, remaining 5 variables were non-significant. The variables which appeared significant were education level of household head, social status of the household head, cultivated land, technology accessibility, farmer's perception, and number of extension contact. The, explanation of result of logit model for each significant variables is discussed below.

Education level: Formal education enhances farmers' ability to perceive, interpret, and respond to new events and information's after that, for adoption of new technology. In most studies, educational status of farmers has been found to be positively related to the adoption of new technologies. In this study also it was found to be positively related with the use of renting-in service, and its coefficient was significant at 1% probability level. The interpretation of the odds ratio implied that if other factors are held constant, the odds ratio in favor of using renting service would be increased by a factor of 1.318 as education level increased by one level (Table.5). This is in line with the result of the impact of row planting of teff crop on rural Household income: A case of Tahtay Maychew wereda, Tigray, Ethiopia by Yonas (2013).

Social status of the household head: This variable has been found to be positively related with renting-in service utilization and significant at 5 % probability level. The results of survey proved the hypothesis those respondents who have participated in social activities were more participated in sorghum threshing renting-in service since, they have access of new information and communication with GO's and NGO and can easily identify modern and useful technology. In table 5, the result of odds ratio increased by a factor of 4.91 as participants at community work using renting-in machine service would increase by one unit, if other variables in the model are held constant.

Cultivated land size: It was found to be positively related with the use of renting-in service, and its coefficient was significant at 1% probability level. In table 5 the result verified the hypothesis that farmers who had large cultivated land can produce more grain output and may be motivated to use improved technology. The interpretation of the odds ratio implied that if other factors are held constant, the odds ratio in favor of using renting-in service increased by a factor of 32.966 when farm size increased by one unit (ha). This result is in line with the research result of Withana *et al.* (2004) on Economic Analysis of Paddy Threshing Methods in Sri Lankan.

Technology accessibility: The accessibility of threshing renting-in services is measured in terms of a farmer's nearness to towns and topography of the area, and is grouped as accessible and non-accessible. It was hypothesized that the use of renting-in threshing services was

increased with nearness to threshing hiring stations and terrain that is conducive to threshing and transporting the thresher. The estimated result showed that, accessibility of the technology was positive and significant at 1% probability level. The odds ratio in favor of using renting-in service increased by a factor of 16.308 for each unit increase in technology accessibility, if other variables in the model were kept constant. This result was similar to a Comparative Assessment of Combine Harvesting Vis-à-vis Conventional Harvesting and Threshing in Arsi Region of Ethiopia (Hassena *et al.*, 2000).

Number of extension contact: This variable exhibited as expected, positive sign and was significant at 1% probability level. This indicated that farmers who had repeated contacted with extension agents were more likely to use renting in service than those who had less and/or no access to these services. The odds ratio of 2.051 for number of extension contact implies that, keeping other variables in the model as constant, the odds ratio in favor of using renting-in service increases by a factor of 2.051 as number of extension contact increased by one. This result was consistent with findings on factors influencing the use of irrigation water at Gedeb irrigation scheme, Machakel wereda, East Gojam zone (Yenetila, 2007).

Perception of farmer: This variable has been found to be positively related with renting-in service utilization and significant at 10% probability level. The odds ratio in favor of using renting-in service increased by a factor of 12.992 for each increased household who had positive perception, if other variables in the model were kept constant. This result was in line with (Mamo, 2002; Tiwari, 2005 and Takele, 2008).

4.3. Impact Estimation

A logistic regression model was used to estimate the propensity scores of sample households which helps to put in to practice the matching algorithm between the treated and control groups. Using logistic regression result by commanding syntax `psmatch2` the logistic regression propensity score matching was found (Table.6). The result revealed a low pseudo- R^2 of 0.27. A low pseudo- R^2 value means user households do not have much distinct characteristics overall and as such finding a good match between user and non-user households becomes possible.

Table.6. psmatch2 logistic regression results for determinants of participation

Renting	Coef.	Std.Err.	z	P> z
Age	-0.030	0.032	-0.94	0.348
Education	0.120**	0.054	2.23	0.026
Family size	-0.112	0.121	-0.92	0.357
Social status	0.760*	0.436	1.74	0.082
Sex	0.668	0.570	1.17	0.240
Off/nonfarm	-0.395	0.950	-0.42	0.678
Market distance	-0.011	0.089	-0.12	0.903
Cultivated land	1.111	1.007	1.10	0.270
Technology	1.503***	0.356	4.22	0.000
Livestock	0.173	0.144	1.20	0.231
Perception	1.177	0.967	1.22	0.224
Number of contact	0.338***	0.095	3.56	0.000
Constant	-3.247	1.735	-1.87	0.061
<hr/>				
Number of obs	=	115		
LR chi2 (12)	=	41,27		
Prob> chi2	=	0.0000		
Log like lihood	=	-56.337338	Pseudo R2	= 0.2681

Source: own survey, 2016

***, ** and * means significant at the 1%, 5% and 10% probability levels, respectively.

Figure.3 below portrays the distribution of the household with respect to the estimated propensity scores. Most of the treatment households are found in the right side of the distribution. On the other hand, most of control households are found in the left side of the distribution. In general the graph shows that there is wide area in which the propensity score of participants is similar to those of non-participants.

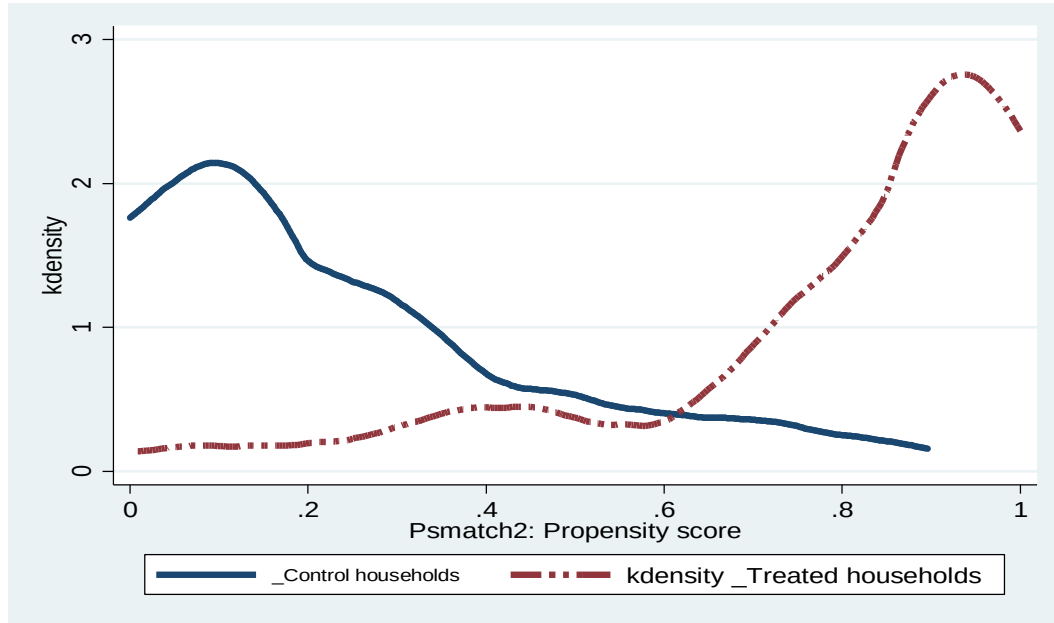


Figure.3. Kernel density of propensity score distribution

Source own computation, 2016

4.3.1. Matching thresher renting-in users and non-users households

Four main tasks were accomplished before matching. First, predicted values of treatment participation (propensity scores) estimated for all participated households and non-participants. Second, a common support condition was imposed on the propensity score distributions of participant household and non-participant household. Third, discard observations whose predicted propensity scores fall outside the range of the common support region. And finally sensitivity analysis was done in order to check the robustness of the estimation whether the hidden bias affects the estimated ATT or not.

As shown in table.6, for control households the estimated propensity score lies in the range of 0.0000008494 – 9613457 (mean = 25.29) whereas for treated households were between 0.00860193 – 0.99996297 (mean = 0.60) The common support region would lie between 0.00860193 and 0.89613457 (mean = 0.39) In other words, households whose estimated propensity score is less than 0.00860193 and greater than 0.89613457 are not considered for the matching exercise. As a result of this restriction, 65 households were discarded. The

histogram in the appendix.8 depicts treated and control households on common support region.

Table.7 Distribution of estimated propensity scores

Households	Obs	Mean	Std.Dev	Minimum	Maximum
Total	180	0.5	0.31	8.49e-07	0.99
Treated	90	0.79	0.22	0.0086	0.99
Control	90	0.21	0.20	8.49e-07	0.896

Source own computation, 2016

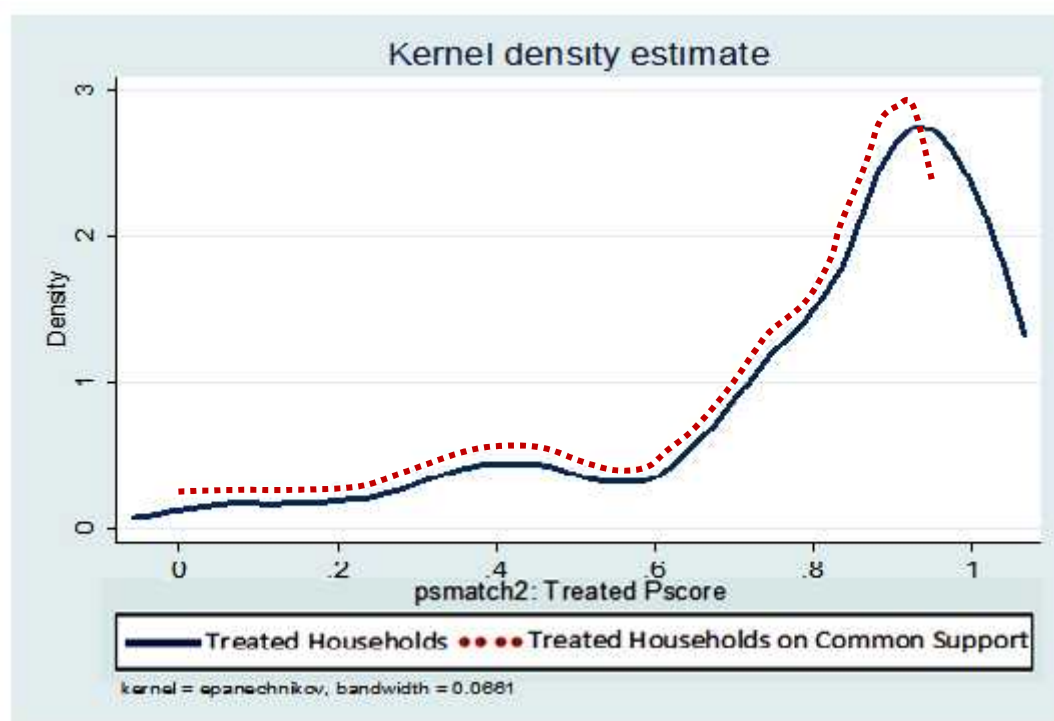


Figure 4: Kernel density of propensity scores of participant households

Source own computation, 2016

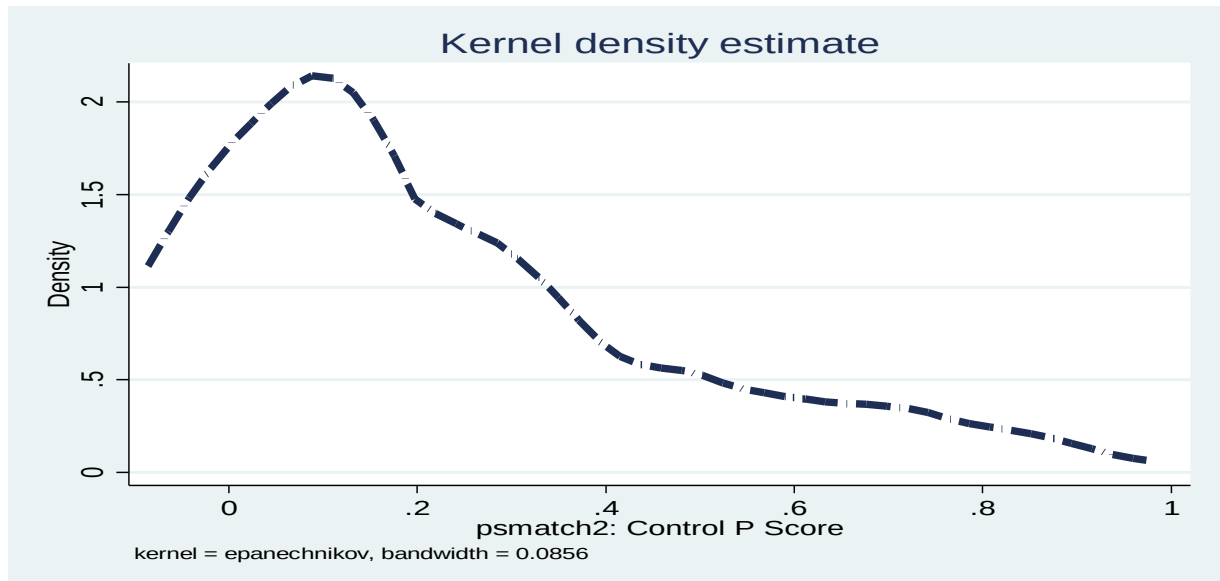


Figure 5: Kernel density of propensity scores of control households

Source own computation, 2016

Figures 4 and 5 depict the distribution of estimated propensity scores, with and without the imposition of the common support condition, for participant and control households, respectively. Most of the participant households have propensity score around 0.8 while majority of the non-participant households have propensity score less than 0.2.

4.3.2. Matching algorithms choice

Balancing test is a test conducted to know whether there is statistically significant difference in mean value of the two groups of the respondents and preferred when there is no significant difference after matched. Accordingly, matching estimators were evaluated via matching the participant and non-participant households in common support region. Therefore, a matching estimator having balanced or insignificant mean differences in all explanatory variables, bears a low pseudo- R^2 value and also the one that results in large matched sample size is preferred.

Table.8. Performance measures of matching estimators

Matching Estimator	Performance Criteria		
	Balancing test* size	Pseudo-R ²	Matched sample
Nearest Neighbor			
1 neighbor	16	0.132	107
2 neighbor	20	0.124	107
3 neighbor	18.2	0.108	107
4 neighbor	19.3	0.117	107
Radius caliper			
0.01	24.2	0.093	93
0.25	11.7	0.063	113
0.5	15	0.140	113
Kernel Matching			
Band width of 0.1	17.7	0.093	113
Band width of 0.25	12.4	0.066	113
Band width of 0.5	12.6	0.085	113

Source: own calculation result (2016)

*Number of explanatory variables with no statistically significant mean differences between the matched groups of participants and non-participants households.

In line with the above indicators of matching quality, kernel matching with 0.25 band width is resulted in relatively low pseudo-R² with best balancing test (all explanatory variables insignificant) and large matched sample size as compared to other alternative matching estimators indicated in Table 8. Then it was selected as a best fit matching estimator.

4.3.3. Testing the balance of propensity score and covariates

Following choosing the best performing matching algorithm the next step is to check the balancing of propensity score and covariate via different procedures by applying the selected matching algorithm. As indicated earlier, the main purpose of the propensity score estimation is not to obtain a precise prediction of selection into treatment, but rather to balance the distributions of relevant variables in both groups.

Table.9. Balancing test for covariate

Unmatched		Mean		% bias	% Reduction bias	T-test	
Variable	Matched	Treated	Control			t	p> t
Fage	U	40.33	41.66	-18.50		-0.99	0.325
	M	40.02	38.66	19.10	-3.20	0.85	0.400
Edulevel	U	3.44	2.16	41.10		2.20	0.030
	M	3.61	3.04	17.90	56.40	0.78	0.435
Famsize	U	6.73	6.93	-10.20		-0.53	0.596
	M	6.67	6.42	13.50	-32.7	0.61	0.544
Sshh	U	0.22	0.14	20.50		1.09	0.277
	M	0.23	0.17	16.20	20.60	0.72	0.472
Sexhh	U	0.93	0.90	12.00		0.61	0.540
	M	0.93	0.97	-14.80	-23.30	-0.87	0.384
Ofnofact	U	0.02	0.01	5.90		0.32	0.753
	M	0.02	0.02	2.30	60.40	0.10	0.921
Marketdi	U	5.52	5.49	2.20		0.12	0.908
	M	5.62	5.32	18.30	-723.00	0.94	0.351
Cultland	U	0.75	0.72	12.70		0.67	0.503
	M	0.74	0.75	-3.50	72.20	-0.14	0.892
Techacce	U	0.40	0.17	51.8		2.79	0.006
	M	0.39	0.41	-2.7	94.8	-0.11	0.911
Lstochol	U	3.76	3.51	15.9		0.84	0.403
	M	3.72	3.61	7.6	52.3	0.30	0.764
Fperstm	U	0.98	0.97	4.0		0.21	0.837
	M	0.98	0.99	-9.6	-139.2	-0.56	0.576
Nextecon	U	3.16	2.24	54.0		2.78	0.006
	M	3.21	2.81	23.5	56.6	1.18	0.242

Source: own calculation result (2016)

The mean bias before and after matching are shown in the fifth columns of Table 9, while column six tales the total bias reduction obtained by the matching process. As a whole, it is obvious that sample differences in the unmatched data significantly go above those in the samples of matched cases. The process of matching thus creates a high degree of covariate balance between the participant and non-participant samples that are ready to use in the estimation procedure. Also, t-values showed that before matching three of selected variables statistically significant differences but after matching all of the covariates were balanced and become statistically insignificant.

Table.10. Chi-square test for the joint significance of variables

Sample	Ps R ²	LR chi ²	p>chi2
Unmatched	0.268	41.27	0.000
Matched	0.066	7.91	0.792

Source: own calculation result (2016)

The low pseudo-R² and the insignificant likelihood ratio tests support the hypothesis that both groups have the same distribution in covariates after matching (Table 10). These results clearly show that the matching procedure is able to balance the characteristics in the participant and the matched non-participant groups. We, therefore, used these results to evaluate the impact of renting-in sorghum threshing machine service on outcome variable among groups of households having similar observed characteristics. This allows comparing observed outcomes for participants with those of a comparison groups sharing a common support. From the above analysis we can suggest that the matching algorithm have chosen is relatively best with the data we have at hand. Thus, we can proceed to estimate ATT for households.

4.3.4. Estimating of treatment effect on treated

With the purpose of achieving the second objective of the study, the following impact showed the treatment effect has been carried out using the propensity score matching model. In this

section, the study presents verifications as to whether or not the sorghum threshing renting-in service has brought significant changes on decreasing household threshing cost of sorghum harvest. The estimation result presented in Table.11 provided a useful evidence of positive effect of the sorghum threshing renting-in service on household decreasing threshing cost of sorghum with finance. Comparing the threshing machine user and non-user households, it had been found that, on average, each participant household has decreased his threshing cost of sorghum by 894.52birr.

Table.11. Estimation of ATT on cost of sorghum threshing.

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Threshing cost (Birr) per ton	ATT	339.66	1234.17	-894.52	64.79	-13.81

Source: own survey result (2016)

Note: S.E. does not take into account that the propensity score is estimated.

4.3.5. Sensitivity analysis result

In this section addressed the issue whether the final evaluation results are sensitive with respect to the choice of the balancing scores. Matching estimators work under the assumption that a convincing source of exogenous variation of treatment assignment does not exist. It is not possible to estimate the magnitude of selection bias using observational data, instead the sensitivity analysis using the bounding approach that involves calculating upper and lower bounds, using the Wilcoxon signed rank test. This rank tests the null hypothesis of no-treatment effect for different hypothesized values of unobserved selection bias. If there are unobserved variables which simultaneously affect assignment into treatment and the outcome variable, a ‘hidden bias’ might arise to which matching estimators are not robust (Rosenbaum, 2002).

Likewise sensitivity analysis was undertaken to detect the identification of conditional independence assumption was satisfactory or affected by the dummy confounder or the

estimated ATT is robust to specific failure of the CIA. The sensitivity analysis of the outcome ATT values to the dummy confounder (Table.12,), with respect to sorghum threshing cost per ton, the CIA remains to be significant/ robust and the results were not sensitive to be confounder.

Table.12. Result of sensitivity analysis using Rosenbaum bounding approach

Gamma	Q_mh+	Q_mh-	p_mh+	p_mh-
1	7.15245	7.15245	4.3e-13	4.3e-13
1.05	7.05678	7.31398	8.5e-13	1.3e-13
1.1	6.9371	7.43966	2.0e-12	5.1e-14
1.15	6.82446	7.56168	4.4e-12	2.0e-14
1.2	6.71814	7.68032	9.2e-12	7.9e-15
1.25	6.61752	7.79583	1.8e-11	3.2e-15
1.3	6.52207	7.90843	3.5e-11	1.3e-15
1.35	6.43135	8.01832	6.3e-11	5.6e-16
1.4	6.34493	8.12568	1.1e-10	2.2e-16
1.45	6.26246	8.23067	1.9e-10	1.1e-16
1.5	6.18364	8.33344	3.1e-10	0
1.55	6.10817	8.43411	5.0e-10	0
1.6	6.03581	8.53281	7.9e-10	0
1.65	5.96633	8.62965	1.2e-09	0
1.7	5.89953	8.72473	1.8e-09	0
1.75	5.83524	8.81813	2.7e-09	0
1.8	5.77328	8.90995	3.9e-09	0
1.85	5.71351	9.00026	5.5e-09	0
1.9	5.6558	9.08913	7.8e-09	0
1.95	5.6	9.17664	1.1e-08	0
2	5.54603	9.26283	1.5e-08	0

Source: own calculation result (2016)

mhbounds Expenditure, gamma(1 (0.05) 2) Mantel-Haenszel (1959) bounds for variable Expenditure

Gamma: odds of differential assignment due to unobserved factors

Q_mh+: Mantel-Haenszel statistic (assumption: overestimation of treatment effect)

Q_mh- : Mantel-Haenszel statistic (assumption: underestimation of treatment effect)

p_mh+ : significance level (assumption: overestimation of treatment effect)

p_mh- : significance level (assumption: underestimation of treatment effect)

Thus, it can be conclude that our impact estimates (ATT) are insensitive to unobserved selection bias and it is result of ranting- in threshing machine service.

5. SUMMARY, CONCLUSIONS AND RECOMMEDATIONS

5.1. Summary and Conclusions

From study result we can summarize and conclude the following points. In this research study has evaluated determinants of renting-in threshing machine and its impact on sorghum threshing cost in Haramaya district at *Fendisha lencha* and *Gende haqa qebeles*. Data for this study was collected from 180 households as of machine user and non-user households using a questionnaire. Using logit regression model the major determinant factors affecting use of threshing renting-in services for sorghum crop was identified. Then, after estimation of the model, eleven variables were hypothesized to influence the use of renting-in service of sorghum thresher; from those variables six of them were found to be statistically significant.

Comparatively, educated households were found more likely participating in renting in service than less educated. Respondents who have participated in social activities were more participated in sorghum threshing renting-in service. Likewise, farmers who have large cultivated land were found more likely participated in renting-in threshing machine than who had less size of cultivated land. Households who had access to the technology were more likely to use renting-in service of sorghum threshing machine. Farmers who have repeatedly contact with extension agents which mean better access to extension service were more likely used renting in service than those who have less and/or no access to these services. Almost all of Renting-in service users and nonuser's households perceive that sorghum threshing renting-in service is a very important technology.

To measure impact of renting-in threshing machine on threshing cost of sorghum the important idea was how much was the reduction of cost of threshing for users of sorghum threshing machine service comparatively non-users? Hence, this study applied a propensity score matching technique, which is a widely applied impact evaluation instrument in the absence of baseline survey data for impact evaluation. Answering this question requires observing outcomes of participant after and before treatment for the same household. However, it was impossible to observe the same object in two states simultaneously. While the treatment evaluator observes the factual for an object, it is impossible to observe the

counter-factual for the same object. One possibility to handle such a problem is to use the threshing cost reduction of households who have no access to renting service to estimate what the cost reduction of those households who have access to renting-in sorghum threshing machine would have been in the absence of renting service.

Participation in renting-in sorghum threshing machine was determined by a combination of factors. Probability of participation is significantly influenced by six explanatory variables. These variables comprised education level, social status of the household head, cultivated land size, technology accessibility, farmer's perception and number of extension contact.

Finding a reliable estimate of the renting-in service impact necessitates controlling for all confounding factors adequately. In doing so, propensity score matching has resulted in 45 participant households to be matched with 70 non-participant households after discarding households whose values were out of common support region. In other words, matched comparisons of different outcome of interest were performed on these households who shared similar pre-participation characteristics except the treatment participation effect. The resulting matches passed on many process of matching quality tests such as t-test, reduction in standard bias and chi-square test. Propensity score matching method was applied to analyze the impact of renting-in threshing machine on the household reducing cost of threshing sorghum. In matching processes, kernel matching with band width of 0.25 was found to be the best matching algorithm. Propensity score matching method result revealed that household that participated in renting-in service have got 894.52 birr lower cost of threshing of sorghum than not participated.

The average treatment effect on treated was statistically significant. The impact estimation results indicated there are significant differences in outcome variable (net decrease in threshing cost of sorghum) between treatment and comparison households, which could be attributable to the participation in machine renting service. The effect of renting-in service on household cost of threshing of sorghum was lower for the participant households. The mean increase in cost of threshing for non-treated is 894.52 birr while that of treated is -894.52. Both regression and propensity score matching method results revealed that sorghum threshing renting-in service has significant impact on household sorghum threshing cost.

Households participated in renting-in service had negative sign the negative sign was because of cost. Renting-in cost was reduced for participant households by -894.52birr than non-participant.

5.2. Recommendations

Based on the empirical findings reported in this thesis, the following recommendations are forwarded. Renting-in sorghum threshing service is important development effort to ensure reducing threshing cost, drudgery and time saving, for farmer households if properly implemented. Based on the empirical findings reported in this thesis, the following recommendations are forwarded:

All farmers, particularly those without an education, need to be informed of the benefits of sorghum threshing machine to increase adoption and reduce cost between literate and illiterate farmers. Strengthening educational capacity of whole community leads to getting adoption of new technology and increase household income. Therefore, farmer's education improvement program should be strengthened.

Government and other development institution should increasing household participation in sorghum threshing renting-in services through fabricating more threshers and inviting privet sectors for investing their capital in this area for manufacturing sorghum threshers. Attention should be given to pick up and develop the capacity of existing workshops in using updated machines and technologies. And capacity building for existing machine shop employees and researchers should be done through training, improving work facility and their education level.

Government and other stakeholders should provide support through the establishment of more extension services in the area of threshing machine and renting-in service and other income generating projects that can assist farmers to produce their production with less cost.

Moreover, policies need to be directed towards the research study, sample prototype production, demonstration; adoption scaling up and multiplication of the threshing machine to sorghum growing areas in the country.

Finally, Fedis agricultural research center should revise its service schedules for farmers. From the research center for instance the way of getting threshing machine is not customary and encouraging. To make understandable having one sorghum threshing machine from the research center the farmer should make available each row materials requirement. That is he should purchase all row materials required for production of the machine from building material shops and fabricate some parts of the machine like pulleys from Dire dawa private machine shops and to pay on cash to the center for labor and machine cost. As well, getting the machine needs more than two months.

To clarify the above paragraph with simple illustration supposed to fabricate the machine required 3.1 pieces of iron sheet thus, the farmer should provide 4 pieces of iron sheet. The price of 1piece of iron sheet is 3,000 birr. So in material the farmer was losing 0.9 pieces of iron sheet. In terms of money he was lost 2700birr. Consequently we can imagine how the farmers can lose with in total machine parts. This makes the farmer wasting un-necessary costs

However, need of the farmers are purchasing readymade machine directly with cash. This reduces loss on un-necessary row materials cost, labor cost, machine cost transportation cost and other expenditures. Additionally the farmer is saving time and encouraged using the technology.

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APPENDICES

Appendices

Appendix1. Conversion Factor

Appendix table 1. Conversion factor for Adult equivalent

Years of age	Men	Women
0-1	0.33	0.33
1-2	0.46	0.46
2-3	0.54	0.54
3-5	0.62	0.62
5-7	0.74	0.70
7-10	0.84	0.72
10-12	0.88	0.78
12-14	0.96	0.84
16-18	1.14	0.86
18-30	1.04	0.80
30-60	1.00	0.82
60 plus	0.84	0.74

Source: Dercon and Krishnan (1998)

Appendix table 2. Conversion factor for Tropical Livestock Unit (TLU)

Livestock	TLU
Ox	1.10
Cow	1.00
Heifer	0.50
Bull	0.60
Calves	0.20
Sheep	0.01
Goat	0.09
Donkey	0.50
Horse	0.80
Mule	0.70
Poultry	0.01

Source: Abdinasir (2000)

Appendix 3. Correlation Test Result

Appendix table 3. Correlation test between variables

coor rentingu fage edulevel famsize sshh sexhh ofnofact marketdi cultland techacce fperstm nextecon (obs= 180)

	rentingu	fage	edulevel	famsize	sshh	sexhh	ofnofact	marketdi	cultland	techacce	fperstm	nextecon
rentingu	1.0000											
fage	-0.0562	1.0000										
edulevel	0.4299	-0.3408	1.0000									
famsize	-0.0387	0.6844	-0.2743	1.0000								
sshh	0.3103	-0.2038	0.5368	-0.1271	1.0000							
sexhh	0.1558	0.1087	0.0676	0.1261	0.0859	1.0000						
Ofnofact	0.1078	-0.0730	0.1251	-0.0262	0.0028	-0.0056	1.0000					
Marketdi	0.0782	-0.1350	0.1105	0.0017	0.0357	-0.0828	0.1875	1.0000				
cultland	0.2704	0.5000	-0.0573	0.4359	-0.0647	0.1623	0.1308	0.0981	1.0000			
techacce	0.3817	-0.0646	0.0715	-0.0080	0.0030	0.0210	0.0624	0.0607	-0.0977	1.0000		
fperstm	0.2489	0.0682	0.1976	0.0457	0.1169	0.2175	0.0626	-0.0304	0.2037	0.0024	1.0000	
nextecon	0.4615	0.2423	0.1204	0.2265	0.0761	0.1185	-0.0058	0.0277	0.4245	0.1000	0.2510	1.0000

Source: own computation result (2016)

Appendix 4. Multicollinearity test Result

Appendix table 4. Multicollinearity test for explanatory variables

Variable	VIF	1/VIF
Fage	2.35	0.425040
famsize	1.99	0.502587
cultland	1.74	0.575034
edulevel	1.68	0.596965
Sshh	1.43	0.698957
nextecon	1.34	0.745215
fperstm	1.16	0.859771
marketdi	1.11	0.897011
ofnofact	1.09	0.914653
Sexhh	1.09	0.916126
techacce	1.05	0.947997
Mean VIF	1.46	

Appendix 5: Goodness of Fit

Appendix table 5. Estimation Goodness of Fit

estatgof

 Logistic model for rentingu, goodness-of-fit test

number of observations = 180
 number of covariate patterns = 179
 Pearson chi2(167) = 244.65
 Prob> chi2 = 0.0001

Appendix 6: Heteroskedasticity Test Result

Appendix table 6. Test for Heteroskedasticity

estathetest

 Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

Ho: Constant variance

Variables: fitted values of rentingu

chi2(1) = 1.65
 Prob> chi2 = 0.1984

Appendix 7: Goodness of test

Appendix table 7. Goodness of test

estat classification Logistic model for rentingu

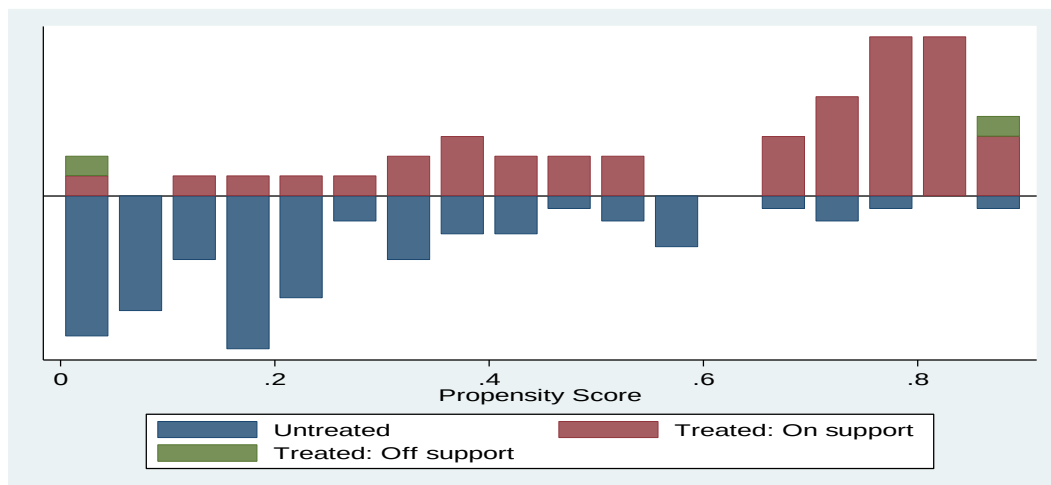
Classified	True		Total
	D	$\sim D$	
+	76	12	88
-	14	78	92
Total	90	90	180

Classified + if predicted $\Pr(D) \geq .5$ True D defined as rentingu $\neq 0$

Sensitivity	$\Pr(+ D)$	84.44%
Specificity	$\Pr(- \sim D)$	86.67%
Positive predictive value	$\Pr(D +)$	86.36%
Negative predictive value	$\Pr(\sim D -)$	84.78%

False + rate for true $\sim D$	$\Pr(+ \sim D)$	13.33%
False - rate for true D	$\Pr(- D)$	15.56%
False + rate for classified +	$\Pr(\sim D +)$	13.64%
False - rate for classified -	$\Pr(D -)$	15.22%

Correctly classified	85.56%
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Appendix figure1. Histogram of propensity score for kernel density matching algorithm

Source: Own computation (2016)

Appendix 8: Contingency Coefficient Test Result

Appendix table 8. Contingency coefficient test for discrete variables

Variables	Sex of the house hold head	Social status of the households	Off/nonfarm activities	Farmer's access to farm the technology	Farmer's perception
Contingency coefficient	0.154	0.296	0.107	0.357	0.242

Appendix 9. Survey Questionnaire

Appendix table 9. Survey Questionnaire for Data Collection

Questionnaire Number_____ Name of the Enumerator_____

Signature_____ Date _____ Name of interviewee_____

Name of peasants association _____ Name of district Haramaya

1. Household characteristics of the respondents

1.1. Sex of the household head _____ 1.Male 2. Female

1.2. Marital status of the household head _____ 1. Single 2.Married 3.Widow 4. Divorced

1.3. Age of the household head _____ Years.

1.4. Education level of the household head in years_____ (0 if illiterate)

1.5. How long have you been in farming? _____ Years

1.6. User/non-user household heads_____ 1. If sorghum thresher user, 2. if non-user

1.7. Do you have another occupation than farming? _____ 1.Yes 2.No

1.8 If yes, in what type of activity you have been engaged? 1. Trading

2. Handicrafts 3.Weaver 4. Others (specify) -----

1.9. What is the type of house you own? _____ 1.Grass roofed 2. Corrugated iron roofed

3.other specify _____

1.10. Are you management member of any Social Organizations? _____ 1.Yes 2.No

1.11. If yes, in which ones? _____ 1.Peasant association 2. “Eder” 3.others (specify)

2. Family member’s information

No	Name of member(start with HH head)	Relation to HH head	Sex	Age	Education level	Marital status	Religion	occupation
1.								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

Relationship	Marital status	Education level	Occupation
1=HH head	1=Single	0=Illiterate 1=Farmer	
2=Spouse	2=Married	If literate 1=Read &write	2=Trader
3=Son	3=Divorced	2=Primary (1-8)	3=Student
4=Daughter	4=Widowed	3=Secondary (9-10/12)	4=Unemployed
5=Others specify	5=specify other	4=Above 5=Specify any other	

2.1. Number of family members permanently working

1. Full time on farm _____ 2. Part time on farm _____

3. Farming system

3.1. How much is your size of land in hectare? _____

1. Cultivated land size _____ 2. Grazing land size _____ 3. Fallow land size _____

4. Home stead land size _____ 5. rented-in land size _____

6. Rented-out land size _____ 7. Other specify _____

3.2. How many hectares do you cultivated in the last year 2015? _____

1. Owned _____ 2. Rented-in (shared) _____ 3. Rented-out _____

3.3 Farm size in hectare and rate per hectare in Birr

Description	Land size (hectare) (1hec.=8temad=8kindii)	Renting cost(birr)
Rented-in		
Rented-out		

3.4. The types of cultivated crops, vegetables, fruits grown & area allotted for each crops

No.	The types of cultivated crops, vegetables and fruits last year	Area in hectare	Output obtained (kg)	Unit price	Total price(Birr)
1	Sorghum				
2	Maize				
3	Wheat				
4	Teff				
5	Barley				

6	Haricot bean				
7	Beans				
8	Millet				
9	Peas				
10	Potato				
11	Sweet potato				
12	Onion				
13	Cabbage				
13	Tomato				
14	Carrot				
15	Root beat				
16	Peppers				
17	Garlic				
18	Chat				
19	Sugar cane				
20	Banana				
21	Mango				
22	Coffee				
23	Papaya				
24	Orange				
25	Others, specify				

3.5. How was the yield of your crops during the 2015 crop season compared to the previous year(s)? _____1.Very high 2.High 3.Low 4.Very low 5.Medium

3.6. Was the weather condition favorable for crop production in the last production season?_____1.Yes 2.No.

3.7 If the answer is no, what was the existing problem? _____

1. Shortage of rain fall 2. Flood and snow 3. others specify

3.8. How do you express the fertility of your land? _____

1. Fertile 2. Moderately fertile 3. Less fertile 4. Infertile

4. Livestock production

4.1. Do you own livestock? _____ 1. Yes 2. No

4.2. For each of type of animals, list the number you own.

No	Type of livestock	number owned	unit price in birr	Total price	No	Type of livestock	number owned	Unit price in birr	Total price
1	Cows				6	Heifer			
2	Oxen				7	Calves			
3	Goat				8	Chicken			
4	Sheep				9	Beehives - modern - local			
5	Donkey				10	Other			

4.3. Did you face shortage of oxen during this crop season? _____ 1. Yes 2. No.

4.4 If yes, how did you overcome it? _____

1. Hiring 2. Borrowing 3. Exchange arrangement 4. Others

4.5. If you hired a pair of oxen, the cost is _____ birr per season

5. Threshing practices

5.1. How do you thresh your harvest? _____ 1. With thresher 2. Manually (traditionally)

5.1.1. If it is with machine is it yours? _____ 1. Yes 2. No

5.1.2. If not yours, do you use renting service? _____ 1. Yes 2. No

5.1.3. For which crop do you use? _____ 1 sorghum 2, Maize 3.If other mention

5.1.4. How many quintals of sorghum you get from your harvest? _____

5.1.5. How much time required on machine for your total harvest? _____ Hour

5.1.6. How much time needed for threshing one quintal using thresher machine?

_____ minute

5.1.7. How much you pay per total harvest? _____ birr

5.1.8. How much you pay per quintal? _____ birr

5.2.0. How long have you been using renting service for sorghum threshing? _____ years

5.2.1. Does threshing sorghum with machine have impact on reduction household

expenditure? _____ 1.Yes 2.No

5.2.2. Does threshing sorghum with machine have impact on household time reduction?

_____ 1.Yes 2.No

5.2.3. Does threshing sorghum with machine have impact on reducing hard work?

_____ 1.Yes 2.No

5.2.4. Do you have interest to purchase sorghum threshing machine? _____

1. Yes 2. .no

5. 2.5. What are labor and material requirements on machine for sorghum threshing?

Table 1.Quantity of labors, materials requirement and its expenditure

No	Laborer and Material requirement	Quantity (number)	Payment per day(birr)	Total payment (birr)
1	Laborer			
2	Family labor men			

3	- women				
4	- children				
No	Food items	Unit quantity		Unit price(birr)	Total cost (birr)
1	- meat	kg			
2	- bread	pcs			
3	- oil	lit			
4	- abesh	kg			
5	- rise	kg			
6	- onion	kg			
7	- grain powder	kg			
8	- milk	lit			
9	-hojaa	lit			
10	-water	lit			
11	-salt	kg			
12	-cigarette	packet			
13	-chat	kg			
14	-tomato	kg			
15	-any other	Pcs/kg/lit			
Total					

5.3.1 If you are not user of renting service for sorghum threshing, what is the reason? _____

1. My harvest is less 2. My farm plot is very far from renting service

3. High renting cost 4. Other specify _____

5.3.2. If you are threshing manually, what are the quantity of labor, materials requirement and its expenditure?

Table 2. Labor, material requirement and its expenditure for manual threshing

No	Laborer and Material requirement	Quantity (number)	Payment per day(birr)	Total payment (birr)
1	Laborer			

2	Family labor men - women - children				
3					
4					
No	Food items	Unit quantity		Unit price(birr)	Total cost (birr)
1	- meat	kg			
2	- bread	pcs			
3	- oil	lit			
4	- abesh	kg			
5	- rise	kg			
6	- onion	kg			
7	- grain powder	kg			
8	- milk	lit			
9	-hojaa	lit			
10	-water	lit			
11	-salt	kg			
12	-cigarette	packet			
13	-chat	kg			
14	-tomato	kg			
15	-any other	Pcs/kg/lit			
Total					

5.3.3. How much total threshing (manually) time required for your harvest? _____Hours

5.3.4. How much time required threshing per quintal manually? _____hour

5.3.5. How much manual threshing expenditure per harvest? _____birr

5.3.6. How much manual threshing cost per quintal?_____ birr

If you may add efficiency of threshing machine in terms of reducing post-harvest loss as compared to manual threshing.

How much do they willing to pay for time saved, energy saved, *etc* by using thresher machine as compared to manual threshing

6. Access to infrastructure and market

6.1. What is the distance from main road to your home? ____ Km

6.2. How far is the nearest market from your home? ____ Km

6.3. Do you produce for market? _____ 1.Yes 2.No

6.4. What is the problem in marketing your product? _____ 1.Transportation problem

2. Market place is very far 3. Low price 4.Other (specify) _____

6.5. Did you get reasonable price for your product? _____ 1.Yes 2.No

6.6. If No, what are the reasons? _____ 1.More number of suppliers

2. Few number of demander 3. Brokers' interference 4.Other _____

7. Off/non-Farm Activities

7.1. Are you or any family members who are engaged in off-farm/non-farm activities?

_____ 1.Yes 2.No

7.2. If yes, how many of your family members and number of days are engaged in off-farm/non-farm activities?

1. Male _____ days _____ 2. Female _____ days _____

7.3. Why members of your family are engaged in off -farm activities? _____

1. Due to shortage of land 2.Due to excess family labor 3. Due to attractive income

4. Due to other reason, specify _____

7.4. When your family labors are engaged in off-farm/ nonfarm activities?

1. during off-season 2.During regular farming activities 3.Both

4. Specify, if any other

7.5. What are the main types of off-farm/non-farm activities and annual income from them?

No.	Non-farm income/Off farm income			
	Source of income	income	Source of income	income
1	Livestock trading		Plowing	
2	Vegetable trading		Harvesting	
3	Shopping		Threshing	
4	Handcrafting		Weeding	
5	Daily laborer		Cultivating	
6	Bee keeping			
7	Chat trading			
8	Other			

8. Household income in 2006 EC

8.1. What is the main source of your cash income? _____

1. Sale of chat 2. Sale of livestock 3. Sale of Food crop 4. Sale of vegetable
 5. Sale of Coffee 6. Other (specify) _____

Table3. Total household income

No.	Sources of income	Income in birr
1	Crop production	
2	Vegetable	
3	Fruit	
4	Livestock	
5	Non-farm/off farm	
Total		

9. Access to Credit and Extension service

9.1. Do you receive any support from DAs? _____ 1. Yes 2. No

9.1.2. If yes, what are the supports given? _____

1. Advice 4. Seed and fertilizer supply

2. Training 5. Other specify _____

3. Demonstration

9.1.3. How often do extension workers or DA's contact you? _____

1. Daily 2. Once a week 3. Once a month

4. Four times a year 5. Annually 6. Other _____

9.1.4. Do you have any sources of credit? _____ 1. Yes 2. No

9.1.5. If yes have you received credit during 2014 cropping season?

1. Yes 2. No

9.2.1.. If yes for what purposes you take the credit? (Multiple answers possible)

1. Purchase of seeds and fertilizer 2. For fattening livestock

3. For renting land/oxen 4. For petty trading 5. Purchase of chemicals

6. Purchase of farm implements 7. Renting of machinery

9.2.2.. How much was the credit you get from the lending agency _____ Birr?

9.2.3. How many times receive the loan in 2014 production year? _____

9.2.4. Major sources of credit in your area:

1. Oromia credit and saving agency 2. Cooperative agency

3. Agricultural office 4. Others/ specify _____

9.2.5. If No, to the question 9.1.5. why not you take credit from these credit agencies?

1. High interest rate 2. No credit facilities

3. No need to take credit 4. Fear of ability to pay 5. Others/ (specify) _____

9.2.6. What are the major credit service problems?

1. Inadequacy of credit 2. High interest rate 3. Loan is not timely available

4. Repayment terms are not favorable 5. Payback period is short

6. Others (specify) _____

Thank You!