SINGAPOREAN JOURNAL OF BUSINESS ECONOMICS, AND MANAGEMENT STUDIES (SJBEM)

www.singaporeanjbem.com Research Paper

ADOPTION AND IMPACT IMPROVED TEFF VARIETIES (QUNCHO) ON PRODUCTIVITY AMONG SMALL-HOLDER FARMERS IN BENISHANGUL-GUMUZ REGION; THE CASE OF NON-TRADITIONAL TEFF GROWING

Correspondence*: Regasa Dibaba, EIAR/Assosa Agricultural Research Center, P.O. Box 265, Assosa, Ethiopia,. Email: regasadibaba@yahoo.com*

ABSTRACT

Adoptions of improved crop varieties like improved Teff varieties (Quncho) have an impact for increasing agricultural productivity and improving the food security status of smallholder farmers in Ethiopia. To get the expected benefit, the technology should be adopted well by smallholder farmers. However, the rate of adoption of improved varieties in the country has remained low. The main objective of the current study was to examine factors affecting adoption of improved Teff varieties (Quncho) at farm level in non-traditional Teff growing areas of Benishangul-Gumuz Region of Western Ethiopia. In addition, the study looks in to preferences of small-holder farmers to varietal attributes that determine the adoption of Teff varieties in the study area. In this study, multistage sampling techniques were employed to select sampled households from two districts. About 249 smallholder farmers were selected randomly from nine kebele administrations proportionally. Both qualitative and quantitative types of data were used. Primary data was collected by using semi-structured questionnaire and personal interview, focus group discussion and key informant interview was used to collect the data. Both descriptive and inferential statistics (Tobit estimation model and propensity score matching (PSM)) were used to analyze the data. In 2015/16 production season, about 58.23% of the sampled household were adopters 41.77% of them didn't adopt improved Teff varieties in the study area. The empirical evidence showed that dependent members of the households, land allocated to cereal and horticultural crops had negative and significance effect on area under improved Teff varieties, while livestock ownership (heifer and poultry), access to training and information on Teff, being progressive farmer and social networks have contributed positively and significantly to Teff adoption. The PSM results indicated that adoption of improved Teff varieties had significant impact on Teff productivity of adopters as compared to the non-adopters with increased Teff productivity over 276.6 kg/ha. Moreover, the average treatment effect on the treated (ATT) on productivity of Teff is 656.43 kg while the controls groups harvested around 379.82 kg. The average treatment effect on the treated (ATT) of Teff productivity is greater compared to the non-adopters that has brought about 42.14%, indicating change for being participated on improved Teff production compared to non-users. The Tobit model estimation results showed that improved teff varieties adoption decision of farm households has been determined by access to training and information on new improved teff varieties, social networks with friends, neighbors and relatives, capacity building of farmers being a model in the village, ownership of tropical livestock (poultry and heifers) unit, income gained from teff sale and other institutional and socio-economic factors in the study area. The finding of this study suggest that farmers in the area seek awareness and training on new improved teff varieties, need improving livestock ownership and social networks and access to information and enterprise choices.

Key words: Benishangul-Gumuz, Improved Teff varieties, Intensity, Small-holder farmers, PSM

1. Introduction

Agriculture has the lion share to the overall economic growth and development in Ethiopia and accounts for nearly 46% of GDP and supplies about 70% of the raw material requirements of local industries, source of food and generates 90% of the foreign exchange earnings (CSA, 2016). However, the sector is constrained by the use of inadequate agricultural technologies and the predominance of subsistence agriculture which is made up of smallholder farmers predominantly produce cereal crops (ATA, 2016).

Cereals are the major food crops both in terms of the area coverage and volume of production and accounts for 95% of agricultural production in Ethiopia and contributed 86.68% of the grain production. Maize, wheat, and *Teff* are the most important cereals in terms of volume, accounting for a total of 77% of all cereal production (ATA, 2016) while maize, *Teff*, wheat and sorghum have made 26.80%, 16.76%, 15.81% and 16.20% of the grain production respectively (CSA, 2016).

Therefore, *Eragrostis Teff* (Zucc.) is the most preferred staple food by majority of the Ethiopian population and its center of origin is in Ethiopia. *Teff* has high energy, phosphorus, calcium and iron contents (Fufa *et al.*, 2011). Moreover, the economic contribution of *Teff* indicates that real *Teff* output on average accounted for 6.1% of the real GDP, while growth in real *Teff* output accounted for 6.4% of the total growth in real GDP i.e., 0.67% of the 10.7% growth in real GDP (Fantu *et al*., 2015). However, the current production system of *Teff* cannot satisfy the consumers' demand due to backward and lack of modern technologies (Tareke *et al*, 2013). Its production and productivity is still very low due to traditional agronomic practices, nutrient deficiencies and susceptibility of the crop to lodging (Teklay *et al*., 2016).

Due to economic and food values, the government of Ethiopia has planned to increase *Teff* production from Amhara, Oromia, South Nations and Nationalities and Peoples and Tigrai regions by 2020 aims to export *Teff* to USA and Western Europe (ATA, 2016). However, to fill the demand of local and export markets of *Teff*; non-traditional growing areas like Benishangul-Gumuz region have to be given priority for *Teff* production due to the large availability of cultivable lands and diverse agro-ecologies suitable for *Teff* cultivation.

Besides, it has been given little attention in research, development and public support (CSA, 2013) and the Government has tried to invest in helping farmers increase their crop production and productivity by providing yield-enhancing inputs and benefit farmers from economies of scale (ATA, 2016). *Teff* is among a major cereal crop produced in Benishangul-Gumuz region for consumption and market. To increase *Teff* production and productivity different technologies have been introduced by different stakeholders along the *Teff* value chain. Part of this, improved *Teff* varieties like Kuncho and Tsedey were promoted by research and development organizations.

Adoption of improved technologies is affected by different economic, technological, demographic and institutional factors. Assefa and Gezehegn (2010**)**, pointed out that one of the means by which farm level productivity can be increased is through the introduction and dissemination of improved agricultural technologies to farmers and found that famers with larger land size, farmer living closer to market, and farmers who had closer contact with the extension system are more likely to adopt new technology and use it more.

Despite large efforts that have been made to scale up new farming technologies like *Teff* improved varieties, the decision of smallholder farmers to adopt vary widely based on various technical and non-technical factors that affect their decision. The farmers in the study area have been adopting improved *Teff* varieties.

However, there was no empirical evidence on the determinants of farmers' adoption of *Teff* improved varieties and its impact on productivity Benishangul-Gumuz region. Consequently, it is important to describe the existing adoption level and identify the factors that determine adoption of improved *Teff* varieties. Unlike other researches done on determinants of adoption, our research will fill the gap by analyzing the intensity and impact of improved *Teff* varieties adoption and impact on productivity thereby providing useful information, bridge the existing knowledge gap and helps to enhance the success of *Teff* crop production.

1.1. Statement of the Problem

Eragrostis Teff (Zucc.) is a small cereal grain indigenous to Ethiopia. *Teff* grains are milled into flour and mixed with water in order to form slurry and fermented for two or three days and bake in to a flat soft bread –just like pancake, which is locally known as "Injera" (Haftamu *et al*, 2009). It is predominantly grown in Ethiopia as a cereal grain and widely grown in both high potential and marginal production areas (CSA, 2010). The energy content is only surpassed by maize.

Compared to other cereals, *Teff* is a relatively low risk crop as it can withstand adverse weather conditions. In addition, the crop suffers from fewer disease and pest problems and can grow under water logged conditions and mainly produced for the market because the price is less variable than for other crops (Fufa *et al.,* 2011). *Teff* grows on various soil types ranging from very light sandy to very heavy clay soils and under mildly acidic to slightly alkaline soil conditions. It can also be grown in low rainfall and drought prone areas characterized by protracted growing seasons and frequent terminal moisture stress; that tolerates reasonable levels of both drought and water logging better than most other cereals and cultivation of *Teff* in Ethiopia has partly been motivated by its relative merits over other cereals in the use of both the grain and straw (Miller, 2010).

Besides, it has been given little attention in research, development and public support (CSA, 2013). This is due to its localized importance mostly in Ethiopia (Fufa *et al*., 2011). However, recently improved technologies are increasingly promoted to farmers to address low agricultural productivity in their staple crops (Vandercasteelen *et al,* 2016). In Ethiopia, the Government has significantly invested in helping farmers to increase crop production and productivity by providing yield-enhancing inputs and benefit farmers from economies of scale (ATA, 2016).

Teff is among a major cereal crop produced in Benishangul-Gumuz region for consumption and market. To increase *Teff* production and productivity different technologies have been introduced by different stakeholders along the *Teff* value chain. Part of it *Teff* improved varieties like Quncho and Tsedey were promoted by research and development organizations.

According to (Fufa *et al.,* 2011), previously released varieties have not been widely accepted by farmers because of their varietal attributes like color, despite high yield levels. However, because of its color and yield, Quncho (DZ-Cr-387) variety has become popular. It is one of the new crop varieties which are rapidly expanding to the most *Teff* growing areas of the country with the genetic capacity of the crop's production more than 30 quintals per hectares of land, which is three times more than the local *Teff* but faces the adoption bottle neck (ATA, 2012).

In spite of the government's efforts to address the issue of low productivity, the adoption of improved *Teff* varieties still remains low to be practiced by majority of farmers. This study, therefore, intended to assess the adoption and impact of improved *Teff* varieties (*Quncho*) on productivity, to assess the perception and preference of farmers towards improved *Teff* varieties and factors that affect the adoption decision of small-holder farmers in the study area.Given the above mentioned facts, it is imperative to describe the existing adoption level and identify determinants of improved *Teff* varieties adoption among small-holder farmers. Hence, this study has aimed to identify small-holder farmers' improved *Teff* varieties adoption extent and factors that affect adoption and its effect on productivity in the study area.

1.2. Objectives of the study:

The overall objective of this study is to identify factors that determine adoption of improved *teff* varieties and assess the impact of using improved *Teff* varieties (*Quncho*) in the study area.

The study is particularly expected to address the following specific objectives:

- To identify factors affecting adoption and level of improved *Teff* varieties in study area
- To estimate the impact of improved *Teff* varieties adoption on productivity.

1.3. Significance of the Study

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

Nowadays *Teff* is becoming the most preferred crop both for consumption and market value. However, its production and productivity is still very low due to traditional agronomic practices, nutrient deficiencies and susceptibility of the crop to lodging (Teklay *et al*., 2016). Today, improving *Teff* production is among the top new technology given priority and suggested for small-holder farmers expecting increased productivity of the crops in the country (Geremew *et al*., 2016). Different research reports indicates that there is an increment *Teff* yield due to the adoption of improved *Teff* varieties and have positive impact to farmers' livelihood. *Teff* is one of the very important cereal crops in Ethiopia where it grows under diverse climatic and soil conditions.

As the population increases the demand for *Teff* will also increase. Unless productivity is improved increase in production will come from area expansion. This will have a negative impact on the environment. Already, farmers in some areas are planting *Teff* where it should not be grown. However, lack of improved cultural practices is among the major production constraints contributing to low productivity of *Teff*.

The study was conducted in Benishangul-Gumuz Regional state, Assosa zone and Mao-Komo special district where there is mixed farming systems. The research result could be applicable for different non-traditional *Teff* growing areas especially on intermediate and humid low land agro-ecologies which are characterized by ample arable lands both at smallholder farmers and commercial ones. By pointing characteristics which determines adoption of *Teff* improved varieties, the study would provide important input to the research and development for enhancing adoption of agricultural technologies effectively in general and *Teff* improved varieties in particular.

2. RESEARCH METHODOLOGY

2.1.Description of the Study Area

The study area is located in the Benishangul-Gumuz Regional State at the Western parts of Ethiopia. Benishangul-Gumuz Regional State is found 661 km away from the capital city of the country, Addis Ababa, in the west. It is located at $9^0 30'$- $11^0 30'$ latitude and $34^0 20'$- $36^0 30'$ longitude. Plain undulating slopes and mountains characterize the topography of the region. The altitude of the region ranges mainly between 580 and 2731 meters above sea level. The research was conducted in Benishangul-Gumuz Regional state, Assosa zone and Mao-Komo special district where there is mixed farming systems. There are three administrative Zones, and 1 special district in the region. The common cereal crops grown are maize, sorghum, *Teff*, finger millet and rice, from pulse crops soybean, chickpea and groundnut is the usual crop in the area. Moreover, oil crops like noug, sesame and linseed are grown in some areas.

2.2.Sample Size and Sampling Procedures

The districts were selected purposively based on *Teff* growing potential and improved *Teff* varieties have been introduced. In this study a two stage sampling technique was employed. The first stage was random selection of *Teff* growing Kebele*s* from the study area, followed by selection of sample households randomly. Hence, a total of 9 Kebeles (6 from Assosa and 3 from Mao-Komo districts) *Teff* growing Kebeles was randomly selected. The sampled households were randomly selected from the sampled Kebeles (the lowest level of administrations). Before selecting household heads to be included in the sample, *Teff* grower household heads of each rural kebele was identified in collaboration with kebele leaders, key informants and development agents of the respective rural kebele. Finally, 249 sample households were selected using probability proportional to size considering from each kebeles.

2.3. Data Types, Source and Method of Data Collection

The study used both primary and secondary data sources that are consistent, available, adequate and reliable for the objective intended to be addressed. Independent questionnaires were designed for farmers to collect necessary data from the study area. Quantitative data on demographic characteristics and other basic information is collected from sample households using structured questionnaire. The survey made formal interviews with randomly selected farmers using the pre-tested semi-structured questionnaires. In addition to the questionnaire survey, an informal survey in the form of focus group discussion technique was employed using checklists for farmers to obtain additional supporting information for the study. The discussions were made with key informant farmers, and agricultural and relevant experts. To fill gaps observed during personal interviews, secondary data were obtained from various sources such as reports of bureau of agriculture at different levels, CSA, previous research findings, and other published and unpublished materials, which are found to be relevant to the study. Focused group discussion and key in formant data collection tools was also be used.

2.4. Method of Data Analysis

To change the raw data of the study into fact, both descriptive and inferential statistics were employed. Descriptive statistics such as frequency, mean, percentage, and standard deviation were used in the process of comparing socio-economic, demographic and institutional characteristics of households. Inferential statistics such as t-test and chi-square test, were used to test the statistical significance of variations among the sample households. Econometric analysis is applied to discuss the extent and factors of improved *Teff* varieties and impact on productivity of *Teff* in the study area

2.5. Model Selection and Specification

Tobit Model Specification

Most of the time adoption studies applied dichotomous regression models that explain only the probability of adoption versus non-adoption rather than the extent and intensity of adoption. However, Tobit model is more appropriate to give reliable output of both discreet and continuous variables (Mc Donald and Moffit, 1980) as it measures the probability of adoption and the level of use of the technology. Mathematically, the model can be expressed as;

$$Y_i = \beta_i X_i + U_i \quad \text{If } \beta_i X_i > 0, \ 0, \text{ otherwise} \qquad (1)$$

Where, Y_i = the observed dependent variable, in this case the area under *Teff* improved varieties,
X_i = explanatory variables,
β_i= a Kx_i matrix of parameters to be estimated and
U_i = an independently and normally distributed error term with mean zero and constant variance.
To estimate the parameters of the model the maximum likelihood method were used.
Following Tobin (1958**)**, the expected value of adoption and level of *Teff* improved varieties adoption across all observations will be estimated by:

$$E(Y_i) = X\beta F(z) + \delta f(z) \qquad (2)$$

Where, $z = X\beta/\sigma$, F (z) is the cumulative distribution function, f (z) is the value of derivative of the normal curve at a given point, z is the Z-score for the area under normal curve, β is a vector of Tobit maximum likelihood estimates and σ is the standard error of the error term. As Madalla (1983**)**, justifies the adjusted estimates are the marginal effects of explanatory variables on the expected value of the dependent variable and given by:

$$\frac{\partial E(Y_i)}{\partial X_i} = F(z)\beta_i) \qquad (3)$$

Also the change in the probability of area under improved *Teff* varieties as independent variable X_i change is given by:

$$\frac{\partial F(z)}{\partial X_i} = f(z)\frac{\beta_i}{\sigma} \qquad (4)$$

And the change in the level of adoption with respect to a change in an explanatory variable among technology adopters is:

$$\frac{\partial E(Y_i/Y*>0)}{\partial X_i} = \beta\left[1 - z\frac{f(z)}{F(z)} - [\frac{f(Z)}{F(Z)}]^2\right] \qquad (5)$$

Estimation of propensity scores

We chose PSM for this study due to its relevance in the case of un-availability of baseline data and the treatment assignment is not random and considered as second-best alternative to experimental design in minimizing selection biases (Baker, 2000). According to Rosenbaum and Rubin, (1983**)**, the conditional independence assumption, the ignorable treatment assignment and the assumption of selection on observables, the identification assumption can be expressed as:

$$Yo \perp D \setminus P(X) \qquad (6)$$

Where the symbol ⊥denotes independence and P(X) is the propensity score. Actually, we require an event weaker condition to identify our treatment parameter, that of conditional mean independence:

$$E\big(Yo\setminus D \ = 1, P(X)\big) = E\big(Yo \setminus D = 0, P(X)\big) \qquad (7)$$

By conditioning on we can get an estimate of the unobserved component in the TT parameter. In particular, we can identify the parameter as follows

$$TT(X) = E(Y1\backslash D = 1, P(X) - E(Yo\backslash D = 1, P(X0)$$
$$= E\big(Y1\backslash D = 1, P(X)\big)E\big(Yo\backslash D = 0, P(X)\big) \quad (8)$$

Following Smith and Todd (2005**)**, let be Y_1 be a household's outcome if it adopts improved *Teff* and let Y_0 be a household's outcome non-adoption of improved *Teff*. The impact of adopting improved *Teff* is the difference in the outcome caused by adopting improved *Teff*. To construct an estimate of the average impact of adopting improved *Teff* on those that adopt it the average impact of the treatment on the treated (ATT).

$$ATT = E(Y1 - Yo|S = 1)$$
$$= E(Y1|D = 1) - E(Yo|D = 0) \quad (9)$$

Where D is an indicator variable equal to 1 if the household adopts improved *Teff* and 0 otherwise. Hence, this study applies a propensity score matching to estimate impact of adopting improved *Teff* estimating the counterfactual outcome for participant (Rosenbaum and Rubin, 1983).

There are two approaches to map a common support region for the propensity score distribution; these are minima & maxima and trimming approaches (Caliendo and Kopeinig (2005**)**. Moreover, Leuven and Sianesi (2003) recommend the use of both the common and "trimming" approaches at the same time for the identification (imposition) of a common support. Even though it is recommended to use both approaches together, in evaluation studies using PSM the approach that yields in good match is preferred. Thus, the data set resulted in good matches in the case of minima and maxima approach.

Matching algorithms of participant and non-participant households in Improved *Teff* varieties

Choice of matching estimator is decided based on the balancing qualities of the estimators. The final choice of a matching estimator was guided by different criteria such as equal means test referred to as the balancing test, pseudo-$R^2$and matched sample size (Dehejia and Wahba (2002**)**). Balancing test is conducted to know whether there is statistically significant difference in mean value of per-treatment characteristics of the two groups of the respondents and preferred when there is no significant difference.

2.6. Analytical Frame Work

There are factors that influence the adoption extent of technology such as characteristics or attributes of technologies; the adopters or farmer, which is the object of change agent (extension worker, professional, etc.); and the socio-economic, biological, physical environment in which the technology take place (Cruz, 1987). Adoption of increasing agricultural new technology can be an important option for the farmers to get rid of hunger and food insecurity by improving crop productivity, reducing food price and making more food accessible for the poor households (A.A. Chandio and J. Yuansheng, 2018). Further, promoting the adoption of improved crop varieties in a sustainable manner helps to improve welfare of the households (Asfaw *et al*, 2012). Moreover, factors that affect improved technologies have been studied before. For example, socio-economic factors that influence adoption of improved high-yielding varieties, and the impact level on rice yield and education, experience and farm size (Adedoyin *et al*., 2016), and extension contacts (A.A. Chandio and J. Yuansheng, (2018)and Ologbon *et al*, (2012) were identified as major determinants. Abubakar *et al*., (2016) had also found household size, farm size, experience, social capital, training participation, extension contacts and market distance significantly and positively influenced adoption of rice production technologies in Nigeria. Ghimire *et a*l., (2015) also found that farm size, land type and animal power are the main factors influencing the probability of adopting of improved varieties specific to rice. Hence, based on previously done researches and the researchers' insight the following important variables were expected to influence the area under improved *Teff* varieties.

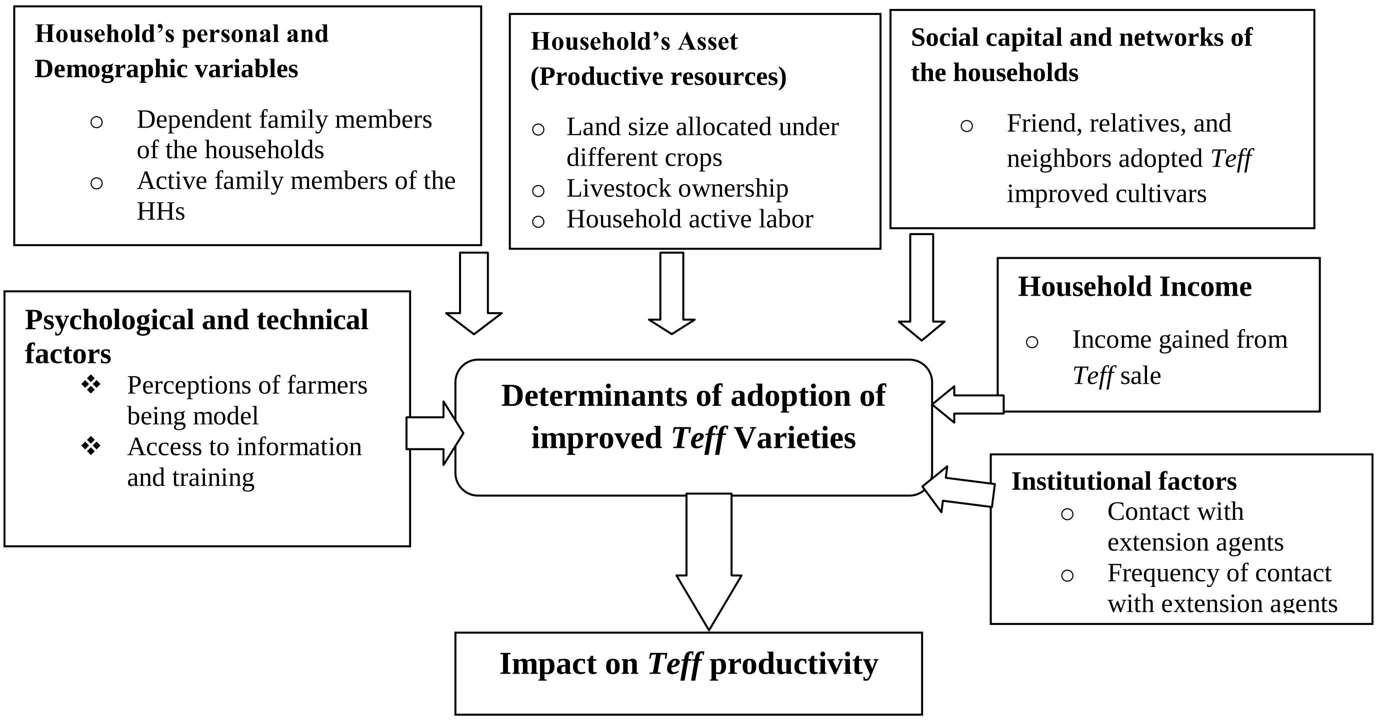

Figure 1. Conceptual frame work of the study

3. RESULTS AND DISCUSSIONS

3.1. Descriptive Analysis

The simple respondents were selected from 9 rural villages or farming communities (6 from Assosa and 3 for Mao-Komo districts) that were considered for the study. Moreover, study employed random selection of sample households from each community, giving a total sample size of 249 (170 for Assosa and 79 for Mao-Komo districts). The number of rural communities and farmers chosen from Assosa district was more because of its large potential of *Teff* producers and well experienced in cultivating *Teff* crop relative to Mao-Komo special district.

Table 1. Sample households from each district

Assosa district			Mao-Komo special district		
Kebele	**Number**	**Percent**	**Kebele**	**Number**	**Percents**
Belmele	13	5.22	Shoshor butuji	26	10.44
Megelle_37	33	13.25	Teja jalisi	36	14.46
Selga_19	23	9.24	Wetse wedessa	17	6.83
Selga_22	31	12.45			
Selga_23	41	16.47			
Selga_24	29	11.65			
Total	**170**	**68.27**		**79**	**31.73**

Source: Survey results, 2015/16

3.1.1. Socio-economic Circumstances of the Sample Households

The mean family size of the total sampled households was around 6 persons. The mean family size of non-adopters and adopters was found to be 6.6 and 5.5 persons respectively. The mean difference of family size for the adopters and non- adopters is statistically significant at 1% probability level. Though households with large family size are expected to adopt improved *Teff* varieties, we found that households with small family size had high probability of improved varieties adoption. Furthermore, the results revealed that the average productive and dependents family member of the households of non-adopters is higher than the adopter counter parts. Non-adopters had about 3 persons while 2 persons for adopters with high mean difference at 1% probability level.

Table 2: Results of the descriptive statistics of the sampled households

Demographic factors	**Non-adopters**	**Adopters**	**Total**	**difference**	**t-test**
Age of the households	44.79	45.07	45.07	-0.48	-0.31
Family size of the households	6.58	5.5	5.93	1.12	3.81***
Households productive family members	3.41	3.29	3.34	0.13	0.77
Dependent household members	3.16	2.19	2.60	.96	3.68***
Economic factors					
Value of farm assets in birr	16418.13	11384.72	13507.24	5033.41	1.40*
Non and off farm income	1414.91	759.72	1036	655.18	1.1
Assets and Resources ownership					
Total land cultivated(ha)	1.57	1.36	1.45	0.21	2.42***
Total land cereal(ha)	1.17	0.98	1.06	0.18	3.01***
Total land pulse and oil crops	0.2	0.22	0.21	-0.02	-0.64
Total land vegetables and fruits	0.02	0.01	0.01	0.02	2.52***
Total land high value crops	0.09	0.12	0.11	-0.03	-1.09
Total land cereal without *Teff*	0.83	0.60	0.69	0.23	3.87***
Total plot of all crops	5.32	5.28	5.3	0.03	0.15
Teff plots	1.08	1.10	1.09	-0.03	-0.58
Total Tropical livestock units (TLU)	3.41	3.06	3.23	0.34	0.87
Oxen(TLU)	0.78	0.6	0.67	0.18	1.54*
Cow(TLU)	1.35	1.20	1.26	0.15	0.68
Heifer(TLU)	0.49	0.77	0.65	-0.3	-3.18***
Bull(TLU)	0.41	0.26	0.33	0.15	1.86**
Calf(TLU)	0.21	0.18	0.20	0.03	0.95
Small ruminants (TLU)	0.33	0.28	0.30	0.04	0.44
Equines(TLU)	0.36	0.26	0.30	0.11	1.56*
Poultry(TLU)	0.04	0.05	0.05	-0.01	-1.59*
Institutional factors & Seed access					
Number of contact with development agents	3.56	5.80	4.87	-2.24	-2.42***
Quantity of non-bought seed(in kg)	5.85	8.58	7.44	-2.73	-3.08***
Quantity of bought seed (in kg)	1.93	2.44	2.22	-0.51	-0.81
Total seed cost incurred	19.04	30.80	25.89	-11.76	-1.34*

*N.B: *, ** & *** indicates the level of significance at 10, 5 and 1% respectively.*

In 2015/16 production year sampled respondent farmers have on average 1.45 ha cultivated land holdings. Out of which, 0.36 ha was covered with *Teff* crop on average. The results revealed that, the cultivated land of non-adopters had larger (1.57 ha) and significant landholdings on average than the adopter counter parts which have 1.36ha. from the cultivated land, land allocated for cereal crops have the largest share than pulse and oil crops, vegetables and high value crops like coffee, hot pepper, and *Khat (Chata edulis forsk*) as indicated in the table below. The total plot allocated under all crops other than *Teff* was 5.3 on average, while for *Teff* was around 1.1 plots on average for the sampled households.

According to the survey results, about 5.85 kg non-bought and 8.6 kg of bought *Teff* seeds were used during the survey time. The mean non-bought seed of the adopters and non-adopters was highly and significantly different at 1% probability level. Thus, implies that the seed rate of adopters was higher than non-adopters as the area covered by adopters is higher than non-adopters as indicated in the table above. Moreover, on average about 2.4 kg of bought seed was used by the adopters while 1.9 kg for non-adopters. The mean seed cost incurred during the survey season was about 19 Ethiopian birr for non-adopters and about 31 Ethiopian Birr for adopters. The implication is that most of the time *Teff* grower farmers utilize stored seeds in the study areas (table 2).

The mean of total area covered under improved *Teff* varieties is greater than the area covered by landraces as indicated in the table below. The average productivity of improved *Teff* varieties was also higher than the land races.

Table 3: Average covered and yield of land races and improved *Teff* varieties

Descriptions	Mean	Std. dev.	Min.	Max.	F-test
Land under improved *Teff*(ha)	0.146	0.21	0.0	1.25	7.72***
Land under landraces *Teff*(ha)	0.217	0.23	0.0	1.25	
Yield of landraces(qt/ha)	436.02	329.2	0.0	1818.18	22.72***
Yield of improved *Teff* varieties(qt/ha)	668.71	395.1	0.0	2000.00	

*Note: ***,** and *, showed that statistically significant at 1%, 5% and 105 respectivelly*

3.1.2. Knowledge and Adoption rate of improved *teff* varieties by district

The survey data revealed that in 2015/2016 production year, about 58.23 % of the sampled household adopts *teff* improved varieties, while 41.77 % of them didn't adopt *teff* improved varieties in the study areas (figure below). However, the rate of adoption varies across the districts. About 64.56 % of the households were non-adopters while only 35.44% had adopted improved *teff* varieties at Mao-Komo special district. The rate of adoption in Assosa district is much higher compared to that of Mao-Komo district. Hence, about 68.82 % of the households adopts improved *teff* varieties whereas the remaining 31.18% of them were non-adopters.

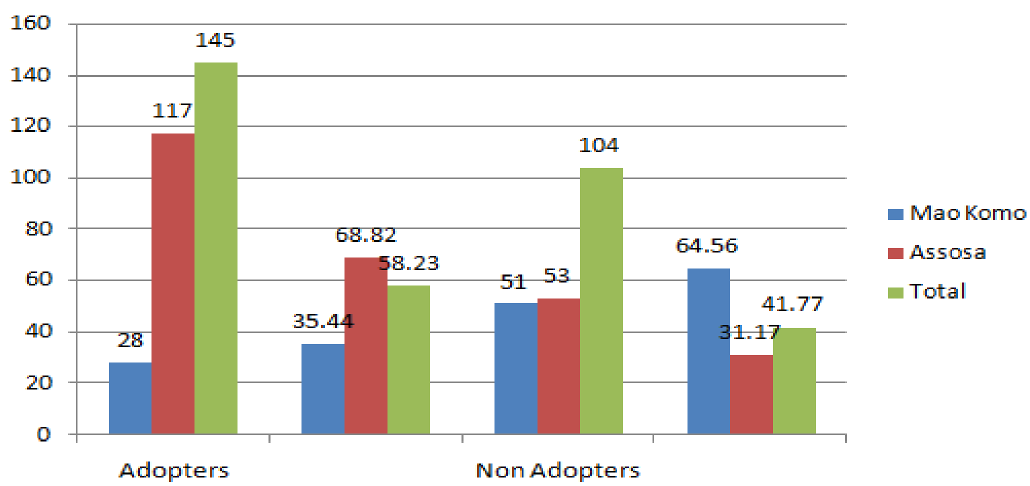

Figure 2: Adoption rate of *Teff* improved varieties by district

Moreover, the study showed that in 2015/2016 production year, about 145 (58.23%) of the sampled household adopts *Teff* improved varieties, while 104 (41.77%) were non-adopters in the study areas. However, the rate of adoption varies across the districts as indicated in the figure above.

About 67.87% of the respondents have grown *Teff* improved varieties in the last ten years while 32.13% did not. However, only 39.23% of them were very certain about the origin and purity of these improved varieties, while the remaining were not sure about the sources and purity of the improved varieties.

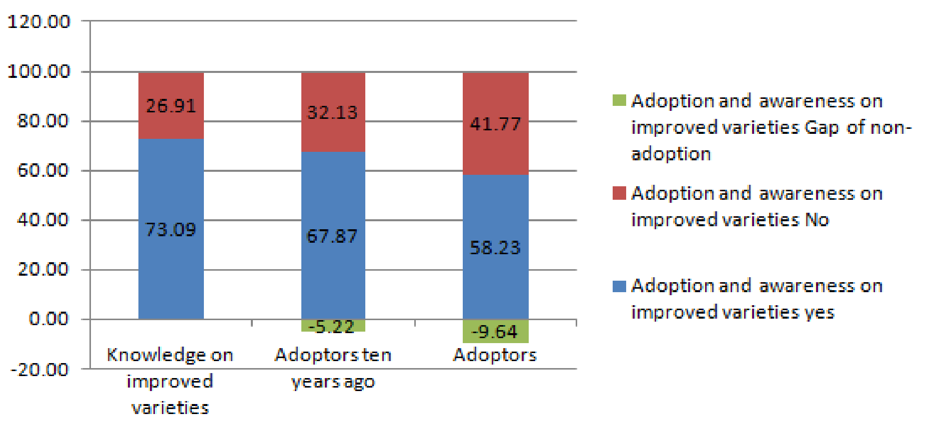

Figure 3: Knowledge of improved varieties and gap of Adoption and non-adoption

The main reasons for none and discontinued adoption were un-availability of seeds, shortage of farmland and lack of draught power, high price of seeds, and lack of access to credit of improved seeds and diseases pests.

3.1.3. Access and source of information on improved *Teff* varieties and other crops

Access to relevant agricultural information makes farmers to be aware of and get better understanding of improved *teff* varieties, which in turn, will facilitate change in the behavior of farmers and may ultimately lead to decision to take risk for adoption. The adopters groups are significantly distinguishable in terms of access to training and information on new varieties. Farmers get access to farm information in different ways. These include participation on events like training, demonstration and field days, farmer-to-farmer information sharing, etc.

Majority of the sample respondents have got information on new improved varieties cultivation from different sources during the last five years. The mean difference between the two groups (adopters and non-adopters) was statistically significant; showing that there is difference between the groups about information on new improved varieties of *teff* among households based on the training received and participation. Moreover, most of the respondents have got access to training and information on insect pests and diseases control, grain and seed markets, and post-harvest handling as indicated in the table below.

Table 4: Access to training and social networks of sampled households

Type of training and information received in the last five years	Adoption status				Total		χ2
	Non-adopters		Adopters				
	No	Yes	No	Yes	No	Yes	
New Improved *Teff* varieties	47	57	28	117	75	174	19.27***
New Improved varieties of other crops	38	66	21	124	59	190	16.29***
Field pest and diseases control on *Teff*	44	60	27	118	71	178	16.67***
Field pest and diseases control on other crops	38	66	22	123	60	189	15.12***
storage pests management	39	65	26	119	65	184	12.02***
Teff grain markets and prices	56	48	47	98	103	146	11.47***
Other crops grain markets and prices	54	50	45	100	99	150	11.03***
Teff seeds markets and prices	56	48	55	90	111	138	6.21**
Other crops seeds markets and prices	54	50	54	91	108	141	5.31**

Source: Survey results, 2015/6

3.2. Results of Econometric Model

3.2.1. Determinants and Intensity of Adoption of improved *Teff* varieties

Tobit model was used to identify determinants and level of adoption of improved *teff* varieties among the sampled households. Hence, the results of the econometric model showed that households with dependent family members have lower area under improved *teff* varieties and decrease the area allocated under improved *teff* varieties by about 4% on average for the whole sample of study, and by about 1 % for those who adopted improved *teff* varieties, and decrease the probability of area allocated under improved *teff* varieties by 2 %. Different types of livestock ownership had significant effect on the area allocated under improved *teff* varieties. The marginal effect showed that a unit increase in tropical unit of heifers increases the probability and intensity of adoption of area under improved *teff* varieties by about 3.3% respectively. Similarly, a one unit increase in poultry ownership increases the probability and intensity of area allocated under improved *teff* varieties by 23 %and 67 % respectively and increases the probability area allocated under improved *teff* varieties by 33 % at 10% significance level.

Table 5: Tobit estimation for Adoption of Improved *Teff* Varieties

Explanatory variables	Area under improved *Teff* varieties				
			Marginal Effects		
	Coef.	Robust Std. Err.	a	b	c
Dependent members of the households(No.)	-0.033***	0.01	-0.01	-0.043	-0.021
Active labor of households(No.)	-0.02	0.015	-0.008	-0.024	-0.012
Oxen owned(TLU)	-0.014	0.028	-0.006	-0.02	-0.01
Heifers owned(TLU)	0.074**	0.032	0.033	0.1	0.047
Donkey owned(TLU)	-0.045	0.044	-0.021	-0.06	-0.03
Poultry ownership(TLU)	0.51*	0.28	0.23	0.67	0.33
Land under other cereal crops(ha)	-0.173***	0.052	-0.078	-0.23	-0.11
Land under fruits and vegetables(ha)	-0.79*	0.46	-0.360	-1.04	-0.51
Training and information on *Teff* (Yes=1,0=otherwise)	0.11**	0.052	0.047	0.14	0.066
Contact with DAs(No.) on *Teff*	0.003	0.002	0.001	0.004	0.002
Model Yes=1, 0=otherwise)	0.07*	0.04	0.035	0.1	0.05
Position (Yes=1, 0=otherwise)	0.065	0.046	0.03	0.09	0.041
Friends, relatives and neighbors improved varieties cultivation(Yes=1, 0=otherwise)	0.27***	0.056	0.11	0.37	0.15
Income gained from *Teff* ('000 Birr)	0.036**	0.016	0.02	0.047	0.023
_Cons	-0.09	0.09			
/Sigma	0.284	0.02			
Number of Obs=249; Pseudo R^2=0.3890; F(14,235)=9.27; Prob>F=0.0000					

[a]Marginal effect on the truncated expected value, dE[TOTAIT*| TOTAIT>0]/dx (for Adopters only)
[b]Marginal effect on the censored expected value, dE[TOTAIM| TOTAIT>0]/dx (for whole sample of study)
[c]Probability of being censored, Pr(TOTAIT I >0)-Total change
***, **, and * are significant at 1%, 5%, and 10% significance levels, respectively.

The total area under cereal crops other than *teff* had highly significant and negative effects on area allocated under *teff* improved varieties by about 23% on average for the whole samples, and by about 8% for those who adopted improved *teff* varieties, and decrease the probability of area allocated under improved *teff* by about 11%. Moreover, income gained from *teff* sale had positive and significant effect on urea under improved *teff* varieties. The results showed that 1000 Ethiopian Birr increase in income gained from *teff* sale had influenced the probability and intensity of area under improved *teff* varieties by 5 % and 2 %, respectively and increase the probability of area allocated under improved *teff* by about 2%.

Access to training and information on new improved *teff* varieties had also positive and significant effect on increasing areas allocated to improved *teff* varieties and has increased the probability and intensity of area under improved *teff* varieties by 14% and 5% respectively for the sampled households and adopters respectively and increase the probability of area allocated under improved *teff* by 7%.

The technical capacity and perception of the farmers as being model farmer had a positive effect on adoption of improved varieties at 10% p-value. Moreover, social capital of individual households like availability of friends, relatives and neighbors who cultivate improved varieties had strong and significant effect on the area allocated under improved *teff* varieties. Hence, farmers with high social networks with friends, neighbors and relatives had affected the probability and intensity of area under improved varieties by about 37% and 11% for the sampled households and adopters respectively and increase the area under improved *teff* varieties by 15%.

3.2.2. Impact of improved Teff varieties Adoption on Teff productivity

Choice of matching estimator and matching algorism

We have make choice of matching estimator based on the balancing qualities of the estimators. Accordingly, based on the matching quality, radius caliper (default to radius matching) with 0.1 width is resulted in relatively low pseudo R^2 with best balancing test (insignificant explanatory variables) and large matched sample size as compared to other alternative matching estimator and selected as a best fit matching estimator for income of *teff* between the two groups.

As shown in table below, the estimated propensity scores vary between 0.1163 and 0.9949 with mean of 0.7164 for adopters (treated) sample households and between 0.0048 and 0.9437 with mean of 0.4013 for non-adopters (control) sample households. Thus, the common support assumption is satisfied in the region of [0.1163-0.9437] for the sample households. This means that households with estimated propensity scores less than 0.1163 and greater than 0.9437 were not considered in the matching undertakings. As a result of this restriction, 35 sample households (18 treated and 17 control sample households) were discarded and 214 sample households were identified to be considered in the estimation process.

Table 6: Distribution of estimated propensity scores for sample households

Group	Mean	Std. Dev	Minimum	Maximum
Treated	0.7164	0.2230	0.1163	0.9949
Control/Comparison	0.4013	0.2507	0.0048	0.9437
Total Households	0.5848	0.2815	0.0048	0.9949

Source: survey estimation results, 2015/16

The figures below portray the distribution of estimated propensity scores, with and without the imposition of the common support condition, for treated (adopters) and untreated (control) households, respectively. As it can be observed from figures 4 and 5, the distribution of estimated propensity scores, with the imposition of the common support condition, whereas participants' propensity score distribution was skewed to the left while it was skewed to the right for non-participants. Both figures portray that there was a considerable overlap or common support between the two groups of respondents.

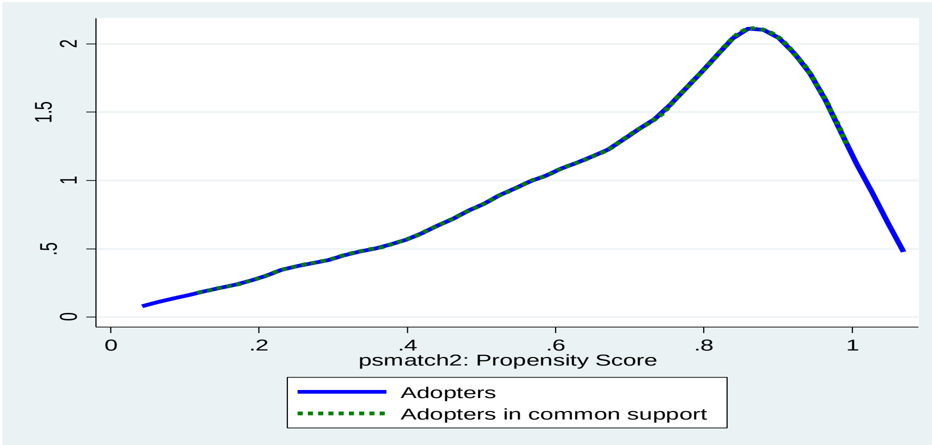

Figure 4: Kernel density of propensity scores of participant households

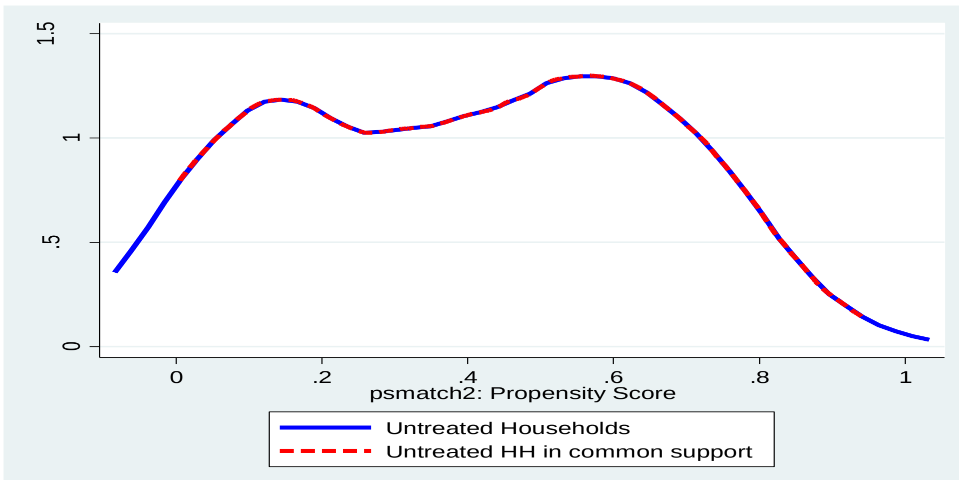

Figure 5: Kernel density of propensity scores of non-users households

Figure 6 portrays the distribution of the household with respect to the estimated propensity scores. In case of treatment households, most of them are found in partly the middle and partly in the right side of the distribution. On the other hand, most of the control households are partly found in the center and partly in the left side of the distribution.

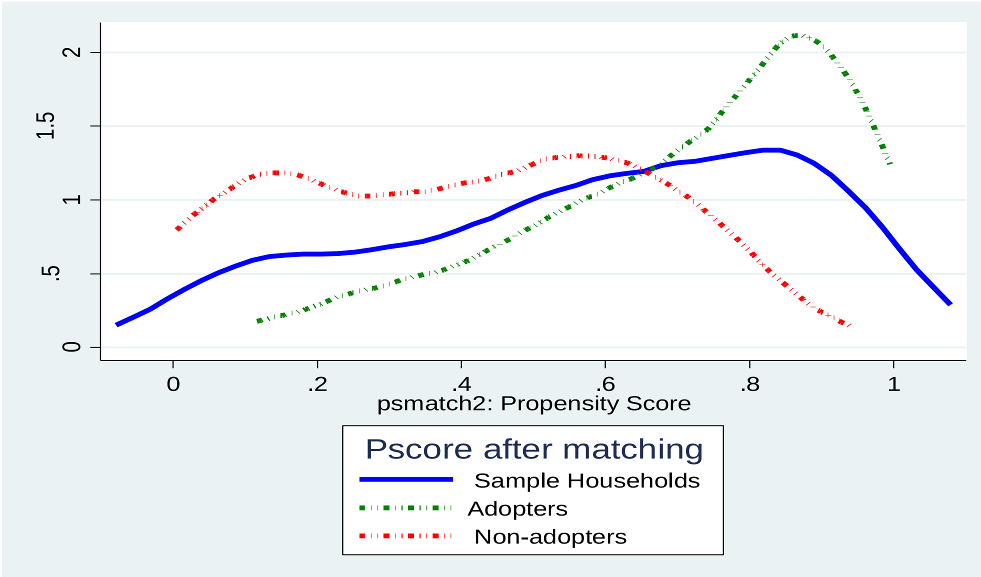

Figure 6: Kernel density of propensity score distribution

Testing the balance of propensity score and covariates

After choosing the best performing matching algorithm the next task is to check the balancing of propensity score and covariate using different procedures by applying the selected matching algorithm (in our case radius caliper matching). 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. The balancing powers of the estimations are ascertained by considering different test methods such as the reduction in the mean standardized bias between the matched and unmatched households, equality of means using t-test and chi-square test for joint significance for the variables used.

After choosing the best performing matching algorithm the next job is to check the balancing of propensity score and covariates using the selected matching algorithm which is radius caliper matching. The main purpose of the estimation of propensity score is to balance the distributions of relevant variables in both treatment and control groups but not to obtain a precise prediction of selection into treatment. Table below shows the balancing tests of the covariates by comparing the before and after matching algorithm. Before matching, there were some variables which were significantly different for the two groups of households. But after matching these significant covariates were conditioned to be insignificant which indicates that the balance that was made in terms of the covariates between participants and non-participants.

Table 7: Propensity score and covariate balance

Variables	Before matching(249)		T-value	After matching (214)		T-value
	Treated (145)	Control (104)		Treated (127)	Control (87)	
Dependent members of the households(No.)	2.602	3.106	3.265***	2.214	2.393	-0.72
Active labor of households(No.)	3.283	3.423	0.805	3.283	2.793	35.6
Oxen owned(TLU)	0.600	0.779	1.544	0.6	0.497	1.06
Heifers owned(TLU)	0.776	0.490	-3.179***	0.776	0.853	-0.95
Donkey owned(TLU)	0.256	0.363	1.558	0.256	0.135	2.37
Poultry ownership(TLU)	0.053	0.041	-1.590*	0.053	0.066	-1.38
Land under other cereal crops(ha)	0.604	0.830	3.865***	0.604	0.581	0.53
Land under fruits and vegetables(ha)	0.001	0.020	2.523**	0.001	0.001	0.53
Training and information on *Teff*	0.807	0.548	-4.552***	0.807	0.766	0.86

(Yes=1,0= No)						
Contact with DAs(No.) on *Teff*	5.807	3.567	-2.415**	5.807	3.25	3.29
Model Yes=1, 0=otherwise)	0.428	0.317	-1.771*	0.428	0.317	1.95
Position (Yes=1, 0=otherwise)	0.669	0.538	-2.096**	0.669	0.710	-0.76
Friends, relatives and neighbors Improved Varieties cultivation (Yes=1, 0=otherwise)	0.869	0.538	-6.211***	0.869	0.807	1.43

Source: survey result, 2015/16

The low pseudo-R^2 and the insignificant likelihood ratio tests support the hypothesis that both groups have the same distribution in covariates X after matching. The results clearly showed that the matching procedure is able to balance the characteristics in the treated and matched comparison groups. The results were used to evaluate the effect of improved *teff* varieties adoption on income generated from being producing improved *teff* varieties among groups of households having similar observed characteristics. This allowed us to compare observed outcomes for participants with those of a comparison group sharing a common support.

Table 8: Tests for the joint significance

Sample	Pseudo R^2	Wald/LR chi^2	Prob> chi^2
Unmatched	0.269	92.08	0.0000
Matched	0.017	5.86	0.951

Source: Survey result, 2015

All of the above tests suggest that the matching algorithm we have chosen is relatively the best for the data at hand. Therefore, we can proceed to estimate ATT for households.

3.2.3. Estimates of average treatment effect (ATT) on productivity of *Teff*

Table below presents the change in the productivity of *teff*. As compared to the non-participants, participants have harvested more of *teff* per hectare of land. Furthermore, the estimated average treatment effect (ATT) of sample households showed that adoption of improved *teff* varieties has strong significant effect on the productivity of adopters (treated groups) smallholder farmers. The result showed that adoption of improved *teff* varieties creates on average positive yield change between adopters and non-adopters of smallholders.

From the table, it is clear that the average treatment effect on the treated (ATT) of productivity of *teff* is 656.43 kg while the controls (untreated) groups harvested around 379.82 kg, indicating the effective level of significance. The result indicates that the propensity of adoption decision to produce improved *teff* varieties has resulted in a positive and statistically significant difference between the two groups of households.

Table 9: Estimation of ATT for productivity of Teff

Outcome variable	Sample	Treated	Controls	Difference	S.E	T-stat
Productivity of *Teff* (kg/ha)	Unmatched	667.763	443.499	224.264	47.733	4.70
	ATT	656.427	379.815	276.613	70.589	3.92***
	ATU	441.925	619.546	177.621		
	ATE			236.368		

Note: *** P < 0.01., Source: Survey result, 2015/16

In general, the adoption decision of households for improved *teff* varieties has generated about 42.14 percent increases in productivity of adopters over non-adopters. The estimated impact of improved *teff* production found that using available improved *teff* varieties have of about 42.14 % change on the smallholders for being participated on improved *teff* production compared to non-users. In another way compared to the non-participants, participants of improved *teff* intervention have harvested about 276.6

kg of improved more of *teff* per hectare of land. In this respect, the difference between the groups of farmers was significant at1% probability level. Overall, the results are in agreement with the findings of other researchers on the impacts of improved agricultural technology adoption by Tolesa *et al*. (2014**)**.

The sensitivity of the evaluation results

The sensitivity analysis is tested to check whether unobserved covariates have effect on the result by creating biases or not. Furthermore, after ATT is found, it is vital to test whether the estimated ATT is effective or not.

Table 10: Sensitivity analysis of the estimated ATT

Gamma	e^r= 1	e^r= 1.25	e^r= 1.5	e^r= 1.75	e^r= 2	e^r= 2.25	e^r= 2.5	e^r= 2.75	e^r= 3
Sig+	0	0	0	0	0	4.4e-16	1.3e-14	1.9e-13	1.8e-08
Sig -	0	0	0	0	0	0	0	0	0

Source: Survey estimation, 2015/16

Above table reveals the sensitivity analysis of the outcome ATT values of the intervention factors or outcome variables to the confounders. As it clearly realized from the table, the significance level is unaffected even if the gamma values are relaxed in any desirable level, shows that ATT is insensitive to external change.

4. CONCLUSION AND RECOMMENDATION

Improved *teff* varieties have been introduced and promoted to increase production and productivity of *teff* crop in Assosa zone and Mao-Komo special district. The adoption of new agricultural technologies is usually hindered and or facilitated by different factors. Hence, we have investigated the determinants of adoption of improved *teff* varieties by taking the area under improved *teff* varieties as a proxy to adoption. Therefore, the empirical evidence from Tobit estimation model revealed that dependent members of the households, land allocated to cereal crops other than *teff* and horticultural crops had negative and significance effect on area allocated to improved *teff* varieties and livestock ownership (heifer and poultry), access to training and information on *teff*, status of the household heads (being progressive farmer) and being practiced improved *teff* cultivars by friends, relatives and neighbors have contributed positively and significantly to improved *teff* varieties adoption in the study areas.

Largely, the study has tried to identify which factors affects adoption of improved *teff* varieties. The negative influence of dependent family size of the households indicates that households with large dependent family members had low rate of improved *teff* varieties adoption. It implies that farmers with high number of dependent family members have a lower adoption rate because of the perception of improved varieties cultivation is labor intensive and prefer not to adopt the new technologies. The negative effects of total area under cereal crops other than *teff* showed that other cereal crops are competing with *teff* and contributed for low area under improved *teff* varieties due to the competitiveness nature of these commodities. Land under fruits and vegetables had also similar effect on area allocated under improved *teff* varieties.

Ownership of different types of livestock has significant effect on the area allocated under improved *teff* varieties. The possible reason is ownership of draught animals and *teff* production is complementary as *teff* straw is used as a feed during off season, while heifers are used for *teff* cultivation and income gained from poultry enable farmers to purchase farm inputs necessary for production. Access to training and information on new improved *teff* varieties had positive effect on increasing areas allocated to improved *teff* varieties. This indicates that creating access to training and information enable to aware farmers on the yield advantages of improved varieties and enhance the technical capacity of farmers on the agronomic practices of *teff* cultivation. The technical capacity and perception of the farmers as being model farmer and social capital of individual households like availability of friends, relatives and neighbors who cultivate improved varieties had positive effect on the area allocated under improved *teff* varieties. Hence, farmers with high social networks with friends, and neighbors and relatives had high adoption rates than their counter parts.

Moreover, the PSM results revealed that though there is a yield deviation from the national average yield adoption of improved *teff* varieties have high impact in productivity of *teff* in the study areas. Given the growing demand for *teff* at international and domestic markets, population growth and consumption patterns production and productivity of *teff* should be increased to fill the demand and supply of the produce. Therefore, we recommend that extension services on *teff*, access over resources like land and livestock, enhancing income of the households from *teff* sale and facilitation and provision of technologies and packages that enhance production and productivity of *teff* are highly important.
Given the growing demand for *teff* at international and domestic markets, due to population growth and consumption patterns production and productivity of *teff* should be increased to fill the demand and supply of the produce. Furthermore, technologies and packages that enhance production and productivity of *teff* like adopting improved *teff* varieties are highly important. Hence based on the results of this study suggestions are drawn as follows:

- Capacity building and awareness creation activities should be done to enhance the farmers' education level through farmers training center and this would in turn improve the adoption of improved teff varieties through increasing farmers' level of understanding on the demonstration of improved varieties. Government extension service should enhance farmers experience on improved teff varieties practices by providing training, proper awareness creation to the technology with frequent farmers' visit that could be convinced farmers toward attributes of improved teff varieties.
- Forcing farmers to adopt any kind of agricultural technology will not bring the expected outcome rather it may aggravated their rigidity not to accept any new farming technologies. Therefore in order to improve farmers' level of adoption of improved teff varieties as well as to enhance their income; extension workers should provide farmers with more practical trainings under farmers' direct participation in the demonstration centers.

ACKNOWLEDGEMENT
The respondents of this study are gratefully acknowledged and we want to convey thanks to those persons who directly or indirectly have provided support and facilitation during data collection, data entry and constructive comments on the manuscript.

5. REFERENCES

A.A. Chandio and J. Yuansheng (2018). Determinants of Adoption of Improved Rice Varieties in Northern Sindh, Pakistan. Rice Science, Vol 25 (2). 103-110.

Adensina, A.A, and M.M. Zinnah. 1993. Technology Characteristics, Farmers' Perception and Adoption Decisions: A Tobit Model Application in Siera-Leone. Agricultural Economics, 13(1):1-9.

A.O. Adedoyin, M.N. Shamsudin, A. Radam, I. AbdLatif. 2016. Effect of improved high yielding rice variety on farmers productivity in Mada. Malaysia. Int J Agric Sic Vet Med, 4 (2016), pp. 39-52.

Alemitu Mulugeta.2011.Factors Affecting Adoption of Improved Haricot bean Verities and Associated Agronomic Practices in Dale Woreda, SNNPS Ethiopia. M.Sc. Thesis Hawassa University.

Assefa Admassie and Gezahegn Ayele, 2010. Adoption of Improved technology in Ethiopia. Ethiopian Journal of Economics. Vol (XIX) (1).

Assefa, K., S. Aliye, G. Belay, G. Metaferia, H. Teffera, and M. E. Sorrells. 2011. Quncho: The First Popular Teff Variety in Ethiopia. International Journal of Agricultural Sustainability 9 (1): 25–34.

ATA (Agricultural Transformation Agency). 2012. Annual Report: Transforming Agriculture in Ethiopia". Addis Ababa, Ethiopia.

ATA (Agricultural Transformation Agency). 2016. Transforming agriculture in Ethiopia. Annual report 2015/2016.

Bayissa Gedefa. 2010. Adoption of Improved Sesame Varieties in Meisso District of West Hararge Zone, Ethiopia. M.Sc Thesis Submitted to Haramaya University.

Becker, J.L., 2000. Evaluating the Impact of Development Projects on Poverty: A handbook for Practitioners. The World Bank Washington, D.C.

Becker, S.O., and M. Caliendo. 2007. Sensitivity Analysis for Average Treatment Effects. The Stata Journal, 7(1): 71–83.

Berhe Tareke, Z. Gebretsadik, S. Edwards, and H. Araya. 2011. Boosting Teff Productivity Using Improved Agronomic Practices and Appropriate Fertilizer. In Achievements and Prospects of Teff Improvement. Proceedings of the Second International Workshop, November 7-9, 2011.

Caliendo, M. and Kopeinig, S. 2008. Some Practical Guidance for the Implementation of Propensity Score Matching, Discussion Paper No.1588, University of Cologne.

Colman, D. and T. Young, 1989. Principles of Agricultural Economics: Markets and Prices in Less Developed Countries. Cambridge, Cambridge University Press.

CSA (Central Statistical Agency). 2010. Agricultural Statistics Abstract: Agriculture". Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2013. Agricultural Statistics Abstract: Agriculture". Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2016. Agricultural Statistics Abstract: Agriculture". Addis Ababa, Ethiopia.

Dasgupta,S., 1989.Diffusion of Agricultural Innovations in Village India, Department of Sociology and Anthropology, University of Prince Edward Island, Canada.

Dehejia, R. and Wahba, S 1999. Causal Effects Non Experimental Studies: Reevaluating theEvaluation of Training Programs. Journal of the American Statistical Association, (94): 1053-1062.

Fantu Nisrane Bachewe,Bethelhem Koru,and Alemayehu Seyoum Taffsse.2015.Summary of ESSP Working Paper 89, Productivity and efficiency of small holder Teff farmers in Ethiopia.

Feder, G., Just, R.E. and Zilberman, D.1985. "Adoption of Agricultural Innovation in Developing Countries, A survey". World Bank working paper number 542. The World Bank Washington, D.C., U.S.A. Econ. Dev. Cult. Change 33:255–297.

Feder, G. and D. Umali. 1993. The adoption of agricultural innovations: A review. Technol. Forecast. Soc. Change, 43: 215-239.

Fufa, B., B. Behute, R. Simons, and T. Berhe. 2011. Teff Diagnostic Report: Strengthening the Teff Value Chain in Ethiopia. Addis Ababa, Ethiopia.

Gujarati, D.N., 1995. Basic Econometrics. Third Edition. International Editors. H.N. Abubakar, I.N. Kolo, A.A. Yabagi, Y. Garba., 2016. Adoption of production technologies by lowland rice farmers in Lavun local government areas of Niger state Nigeria. Int J Agric Ext, vol. (4). pp. 49-56.

Haftamu Gebretsadik, Mitiku Haile and Yamoah.C.F. 2009. Tillage frequency, Soil Compaction and N-Fertilizer Rate Effects on Yield of Teff (Eragrostis Teff (Zucc) Trotter) in Central Zone of Tigray, Northern Ethiopia. Agron.J 1 (1): 82 – 94.

Jalan J.and Ravallion M, 2003. "Estimating the Benefit Incidence of an Antipoverty Program by Propensity Score Matching. Journal of Business and Economics Statistics, 21 (1):19-30.

Joachim Vandercasteelen, Mekdim Dereje, Bart Minten, and Alemayehu Seyoum Taffesse 2013.Summary of ESSP Working Paper 60, "Scaling-up adoption of improved technologies: The impact of the promotion of row planting on farmers' Teff yields in Ethiopia.

Joachim Vandercasteelen, Mekdim Dereje, Bart Minten, and Alemayehu Seyoum Taffesse 2016.Summary of ESSP Working Paper 92, "Row planting Teff in Ethiopia: Impact on farm-level profitability and labor allocation".

L. Cochrane and Y. Bekele, 2017. Average crop yield (2001–2017) in Ethiopia: Trends at national, regional and zonal levels. Elsevier, Vol (16). Accessed at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5758922/ Leuven and Sianesi (2003)

Maddala, G. S., 1977. Econometrics, Singapore, McGrow-Hill Book Co.

Maddala, G.S., 1983.Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press, New York.

Maddala, G.S., 1992. Introduction to Econometrics. Second Edition. New York: Macmillan Publishing Company.

McDonald, J.F. and R.A. Moffitt, 1980.The use of Tobit Analysis, Review of Economics and Statistics, 62(2): 318-321.

Miller, D. R. 2010. Teff grass crop overview and forage production guide (second edition).

Nkonya, E., T. Schroeder and D. Norman, 1997. Factors affecting adoption of improved maize seed and fertilizer in North Tanzania. Indian j. Agri.econ. 48(1):1-12.

O.A.C. Ologbon, E.E. Ikheloa, E.O. AkereleAdoption of 'Ofada' rice variety and technical efficiency of rice-based production systems in Ogun State. Nigeria. World J Agric Sci, 8 (6) (2012), pp. 624-631.

R. Ghimire, W.C. Huang, R.B. Shrestha., 2015. Factors affecting adoption of improved rice varieties among rural farm households in Central Nepal. Rice Sci, 22 (1). pp. 35-43.

S. Asfaw, B. Shiferaw, F. Simtowe, L. Lipper, 2012. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. Food Policy, 37 (2012), pp. 283-295.

Teklay T., and Girmay G., (2016): Agronomic and economic evaluations of compound fertilizer applications under different planting methods and seed rates of Teff [Eragrostis Teff (Zucc.) Trotter] in Northern Ethiopia. Journal of the Dry lands, 6(1): 409-422.

Tolesa Alemu, Bezabih Emana, Jema Haji and Belaineh Legesse. 2014. Impact of Wheat Row Planting on Yield of Smallholders in Selected Highland and Lowland Areas of Ethiopia. International Journal of Agriculture and Forestry 4(5): 386 – 393.

Tsibuk Berhe.2015. Factors affecting Adoption of Quncho Teff variety: The case of Medebayazaza Woreda, north –western Admenstration zone of Tigary Redion Ethiopa .M.Sc.Thesis Hawassa University.

Wubeneh Nega. 2003. Farm-Level Adoption of New Sorghum Technologies in Tigray Region, Ethiopia. M Sc. Thesis. Purdue University. USA.

APPENDIX

Appendix 1: Conversion factor used to compute Man- equivalent (labor force)

Category in years	**Male**	**Female**
Less than /<10	0	0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1	0.8
Greater than />50	0.7	0.7

Sources: Storck, *et al. (*1991)