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Determinants of Improved Teff Varieties Adoption and Its Impact on Productivity: The Case of Non-Traditional Teff Growing Areas of Western Ethiopia

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Abstract
Adoptions of improved crop varieties like Teff have an impact for increasing agricultural productivity and improving the food security status of smallholder farmers in Ethiopia. The main objective of the current study was to examine factors affecting adoption of improved Teff varieties at farm level in non-traditional Teff growing areas of Benishangul-Gumuz Region of Western Ethiopia, by using random sampling technique and the data were collected from 249 smallholder Teff growing farmers using face to face interview. Descriptive statistics, Tobit estimation model and propensity score matching (PSM) were employed to analyze the data. 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.
Keywords: Benishangul-Gumuz, Intensity, Participation, PSM

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 percent 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, Oromiya, 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.

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. 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 al., (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.

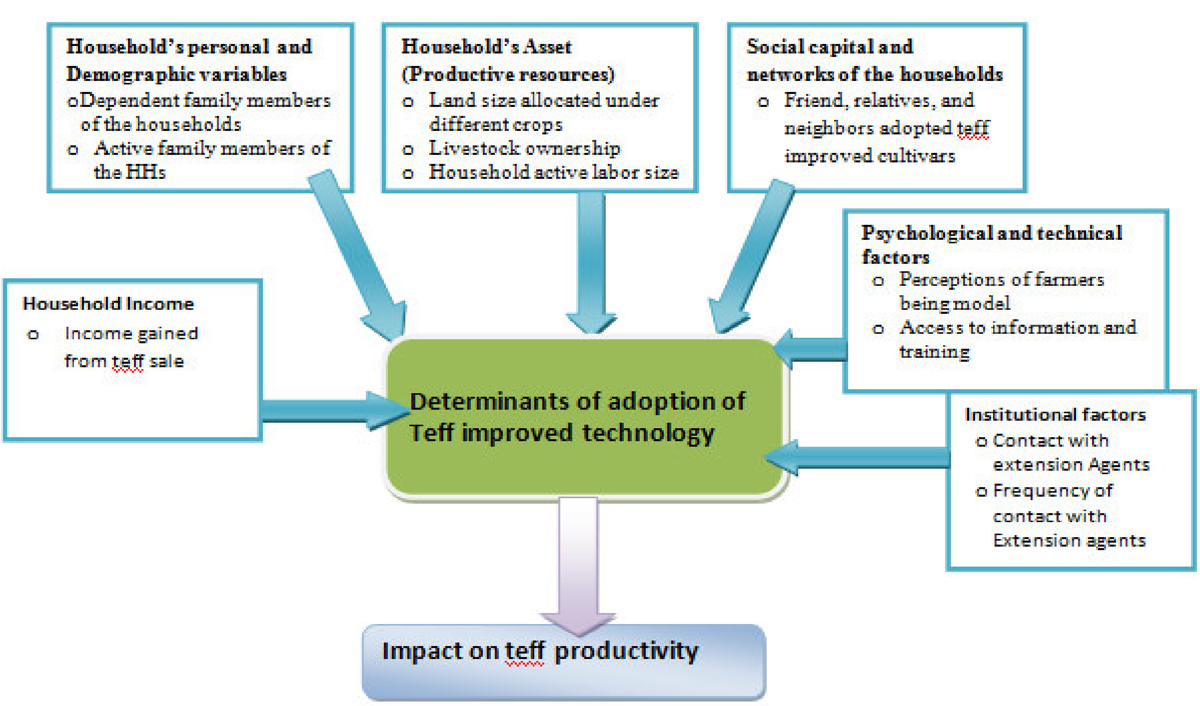

Figure 1. Conceptual framework of the study

RESEARCH METHODOLOGY

Description of the Study Area

The study area is located in the Benishangul-Gumuz Regional State. It is located in the Western part of Ethiopia and stretches along the Sudanese border found at 661 km away from Addis Ababa. It is located at 9◦ 30′- 11◦ 30′ latitude in the North and 34◦ 20′- 36◦ 30′ longitudes in the East. 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. In the study area oil crops like noug, sesame and linseed in some areas can also grow. Hence the study has been conducted at Assosa district of Assosa zone and Mao-Komo special districts which have high Teff production in the region.

Sampling Procedures, data collection and analysis

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 Kebeles 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. Finally a total of 249 sampled households were randomly selected from the sampled Kebeles (the lowest level of administrations).

Model Specification: The Tobit Model

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 Donaled 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 = Xβ/σ, 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:

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

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

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

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

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

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:

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

Where the symbol $\perp$ 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:

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

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

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

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 a test 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.

RESULTS AND DISCUSSIONS

Descriptive Analysis

The study showed that in 2015/2016 production year, 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 below.

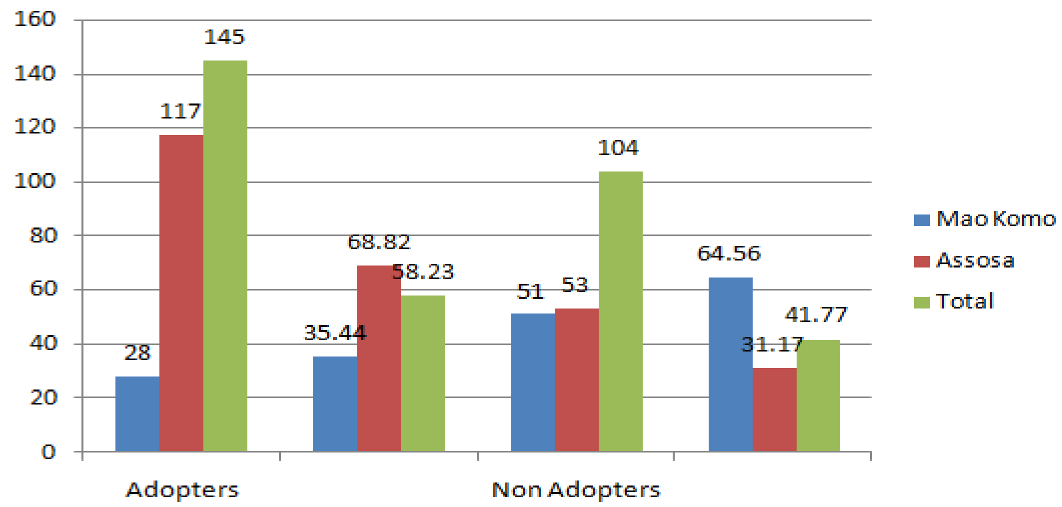

Figure. 2: Adoption rate of Teff improved varieties by district

Table 1: 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	-0.313
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	2.4178***
Total land cereal(ha)	1.17	0.98	1.06	0.18	3.0084***
Total land pulse and oil crops	0.2	0.22	0.21	-0.02	-0.6414
Total land vegetables and fruits	0.02	0.001	0.009	0.018	2.5227***
Total land high value crops	0.09	0.117	0.106	-0.026	-1.0909
Total land cereal without Teff	0.83	0.60	0.69	0.226	3.8651***
Total plot of all crops	5.32	5.28	5.3	0.03	0.152
Teff plots	1.077	1.103	1.092	-0.026	-0.58
Total Tropical livestock units (TLU)	3.41	3.06	3.23	0.34	0.869
Oxen(TLU)	0.78	0.6	0.67	0.178	1.544*
Cow(TLU)	1.35	1.20	1.26	0.148	0.677
Heifer(TLU)	0.49	0.77	0.65	-0.28	-3.179***
Bull(TLU)	0.413	0.262	0.325	0.151	1.8585**
Calf(TLU)	0.214	0.182	0.195	0.031	0.947
Small ruminants (TLU)	0.33	0.28	0.301	0.04	0.4438
Equines(TLU)	0.363	0.258	0.300	0.107	1.5581*
Poultry(TLU)	0.041	0.053	0.048	-0.012	-1.59*
Institutional factors					
Number of Contact with DAs	3.56	5.80	4.87	-2.24	-2.4145***
Production factors (in reference to Teff)					
Quantity of non-bought seed(in kg)	5.85	8.58	7.44	-2.73	-3.0785***
Quantity of bought seed (in kg)	1.928	2.438	2.22	-0.51	-0.81
total seed cost incurred	19.04	30.80	25.89	-11.76	-1.344*
Total Nitrogen Fertilizer (N_2) in kg used	15.01	20.92	18.45	-5.91	-1.5*
Total DAP (N_2PO_5) in kg Used	23.31	42.03	34.21	-18.72	-4.2***
Plowing frequency(No.)	3	3.23	3.13	-0.23	-2.06**
Weeding frequency(No.)	1.87	1.92	1.90	-0.05	-0.5

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

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 2: Average covered and yield of land races and improved Teff varieties

Variables	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	

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

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.

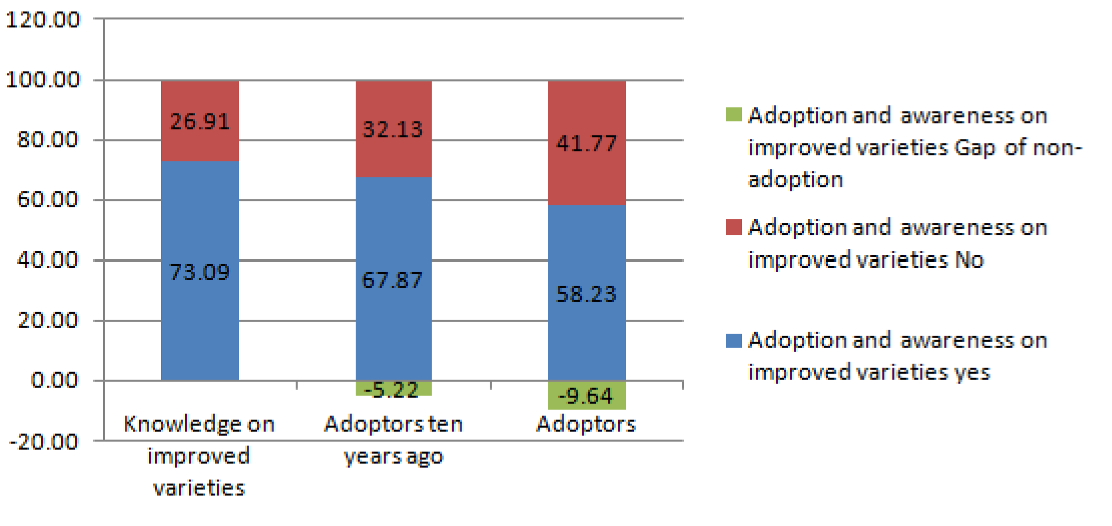

Fig. 3: Knowledge of improved varieties and gap of Adoption and non-adoption

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.

Access and source of information on Teff improved varieties and other crops

Majority of the sample respondents have got information on new improved varieties cultivation from different sources during the last five years. As a result about 174 (70%) and 190 (76.3%) of them have access to training and information on new improved varieties and other crops, respectively. 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 3: 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**
Institutional and social networks of the households							
Friend and families planted improved Teff	48	56	19	126	67	182	33.63***
Friend and families leadership position	48	56	48	97	96	153	4.354**
Coop membership	44	60	76	69	120	129	2.477
Radio ownership	60	44	68	77	128	121	2.82*
Mobile ownership	50	71	54	74	121	128	0.02
Model farmer	71	33	83	62	154	95	3.12*
Community leadership	62	42	71	74	133	116	2.76*
Coop membership	44	76	66	69	120	129	2.477
Beehive ownership	76	28	123	22	199	50	5.210**
Knowledge on recommended rate of fertilizer	73	31	80	65	153	96	5.76**
Applied the recommended rate of fertilizer	93	11	104	41	197	52	11.48***
Participation in field visit of Teff varieties	65	39	74	71	139	110	3.23*
Hosted field day or variety selection	102	2	132	13	234	15	5.31**

The main sources of training and information on new improved varieties, crop protection; post-harvest handling, input and output prices were from different stakeholders along the agricultural extension system. These include government extension services, research centers, neighbor, relatives and friend farmers, radio and television were the main sources of the training and information.

Results of the Econometric Model

Determinants and Intensity of Adoption of Teff improved varieties

Tobit model was used to identify determinants and level of adoption of improved Teff varieties of 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 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 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 4: Tobit estimation for Teff Adoption

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%.

Impact of improved Teff varieties Adoption on Teff productivity

Estimates of average treatment effect (ATT) of 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 5: Estimation of ATT for productivity of Teff

Outcome variable	Sample	Treated	Controls	Difference	S.E	T-stat
	Unmatched	667.763	443.499	224.264	47.733	4.70
Productivity of Teff (kg/ha)	ATT	656.427	379.815	276.613	70589	3.92***
	ATU	441.925	619.546	177.621		
	ATE			236.368		

*** 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 6: Sensitivity analysis of the estimated ATT

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

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 *Teff* improved 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 under 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 improved Teff cultivars of friends, relatives and neighbors have contributed positively and significantly to Teff adoption in the study areas. Moreover, the PSM results revealed that though there is a yield deviation from the national average yield of Teff improved varieties that 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.

Largely, the study has tried to identify which factors affects adoption if 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.

Ownership of different types of livestock ownership 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.

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.

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.

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APPENDIX

Choice of matching Estimator and matching algorism

Table 7 : Performance of matching estimators for sample households

Matching estimator	Performance		
	Balancing test*	Pseudo R^2	Matched sample size
KM			
Bandwidth (0.01)	6	0.031	176
Bandwidth (0.1)	6	0.019	214
Bandwidth (0.25)	6	0.032	214
Bandwidth (0.5)	6	0.072	214
NNM			
Neighbor (1)	6	0.053	214
Neighbor (2)	6	0.027	214
Neighbor (3)	6	0.025	214
Neighbor (4)	6	0.019	214
Neighbor (5)	6	0.019	214
Radius Caliper (0.01)	6	0.029	176
Radius (0.1)	6	0.017	214
Radius (0.25)	6	0.046	214
Radius (0.5)	6	0.104	214

Source: Survey estimation, 2015/16

Table 8: 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

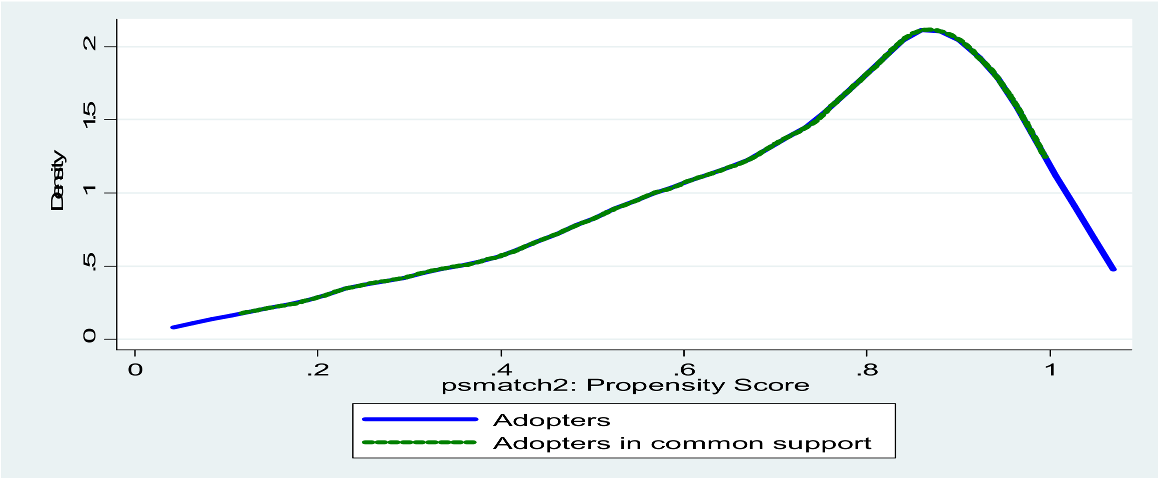

Figure 4: Kernel density of propensity scores of participant households

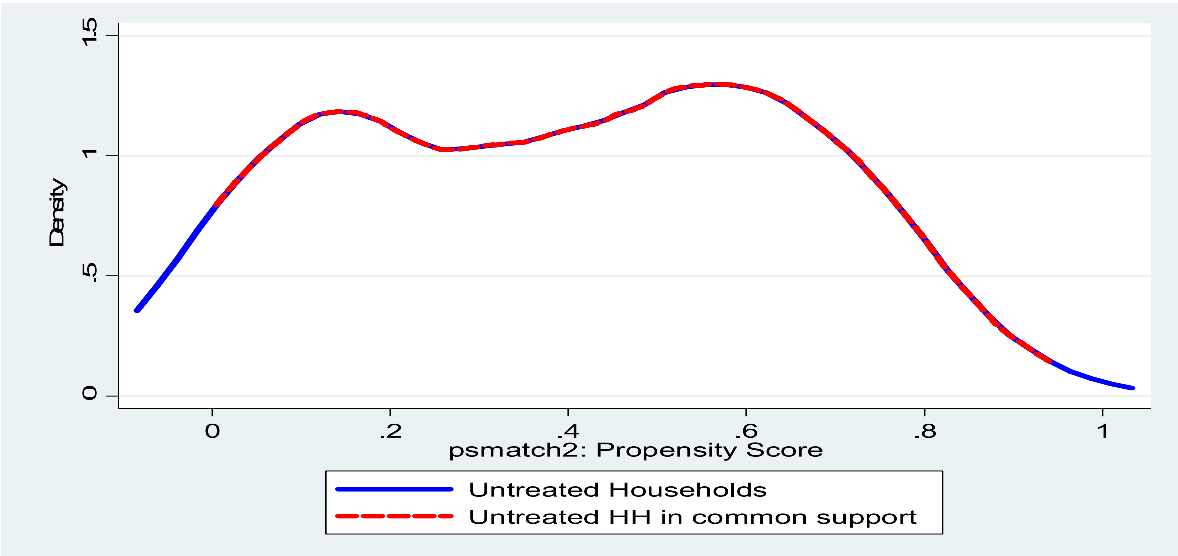

Figure 5: Kernel density of propensity scores of non-users households

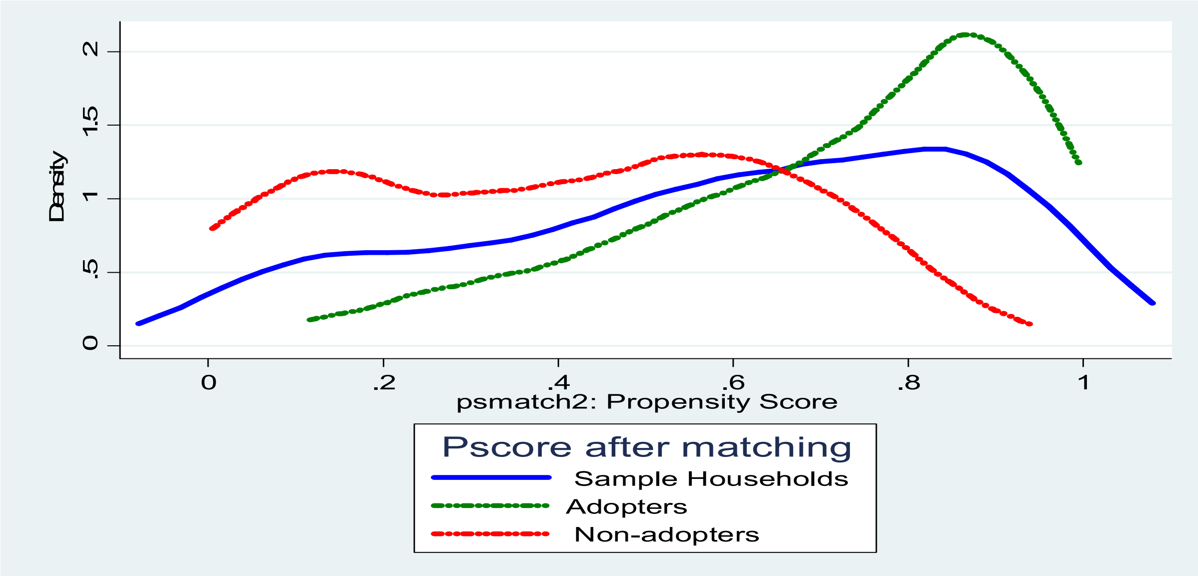

Figure 6: Kernel density of propensity score distribution

Testing the balance of propensity score and covariates

Table 9: Propensity score and covariate balance

Variables	Before matching(249) Treated (145)	Control (104)	T-value	After matching (214) Treated (127)	Control (87)	T-value
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 (Yes=1,0= No)	0.807	0.548	-4.552***	0.807	0.766	0.86
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

Table 2: 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.