Asia-Pacific Journal of Science and Technology : Volume : 26 Issue : 02 Article ID : APST-26-02-03. Research Article

APST

Asia-Pacific Journal of Science and Technology

https//:www.tci-thaijo.org/index.php/APST/index

Published by the Research and Graduate Studies,
Khon Kaen University, Thailand

Adoption of row planting technology and household welfare in southern Ethiopia, in case of wheat grower farmers in Duna district, Ethiopia

Negese Tamirat[1,*] and Jemal Abafita[1]

[1]Department of Economics, College of Business and Economics, Jimma University, Oromia, Ethiopia
[*]Corresponding author: negeseta2016@gmail.com

Received 5 September 2020
Revised 13 December 2020
Accepted 1 January 2021

Abstract

Adoption of yield enhancing row planting technologies is crucial for achieving agricultural growth and development. This study attempts to investigate the factors affecting adoption decision and its impact on income and expenditure in Duna district cross-sectional field survey data gathered in 2018-2019. However, technology adoption and farmers livelihood were poorly related due to lack comprehensive measure of agricultural productivity. A cross-sectional field survey was conducted among 375 wheat growers in Duna district, southern Ethiopia. Descriptive statistics and econometric methods such as binary logit regression and propensity score matching was employed for the data analysis. Sensitivity analysis developed to ensure the validity of the conditional independence assumption. The results of binary logit regression revealed that the technology participant was significantly affected by age, education status, size of family, off-farm income, land holding, livestock holding, quantity of fertilizer used, farmers training center, access to credit and extension services. Adoption was associated with a significantly higher crop yield and expenditure. Sensitivity analysis indicated that there is no hidden bias. The findings suggest that the role of technology adoption at farm level due to higher yield and income could translate in to reduced poverty. Extension office and another concern body should give an important attention to adoption decision which base for enhancing yield. The summary of this technique by policy makers and plan designers could bring better enhancement on wheat cultivator. Improving such a technique is crucial option to enhance wheat grower income, consumption expenditure and crop yield.

Keywords: Adoption, Binary logit, Ethiopia, Propensity score matching, Row planting technology, Wheat, Yield

1. Introduction

Agriculture has been and continues to assume center stage in economic policy of many less developed and developing countries. Consequently, growth in the agricultural sector has been critical to achieving poverty reduction and income growth creating spillover impacts to the industries, services and tourism sectors [1]. However, yield of the agricultural sector in less developed and much of the developing countries are generally low due to poor technological adoption [2-4]. Agriculture is by far the largest sector of Ethiopia’s economy serving as a basis for reducing the country’s food insecurity and source of livelihood for over 80% of its people. The sector accounts 50%, 90%, 85% and 70% of gross domestic product, export revenue, labor force and raw materials respectively. Consequently, the sector has been the crucial element of the country’s agriculture development led industrialization strategy for many years [5].

Among cereal crop wheat is one of the major cereal food crops in Ethiopia. In terms of annual yield, it is the second most important cereal crop with 3.43 m/tons cultivated on land size of 1.63 m/ha [6]. This represents a share of 17% of the cultivated land size and a mean national production of 21.10 quintals/ha, which is by far the lowest compared to the world mean production of 40 quintals/ha [7]. A number of factors have been cited as responsible for such a low level of average yield. First and for most the nature of the agricultural sector which is featured by subsistence and seasonal rain fed, backward technology adoption decision, poor quality agricultural performance, income inequality and massive population increment. Consequently, the country has been difficult to meet their high demand for food security thereby remaining net importer from other countries despite its huge potential for adoption decision and wheat yield [8].

The backward sowing method - the broadcast sowing technique - is the most common and widely employed practice among smallholder farmers in Ethiopia. The method employs broadcasting of seed by hand at high speed a practice with potentially negative consequences. In particular, the tradition of broadcasting seeds is likely to lead to a fall in yield due mainly to the difficulty in hoeing and hand weeding; and the competition with weed resulting from the uneven distribution of the seeds. Wheat is among the cereal crops commonly planted using the backward sowing techniques possibly explaining the considerably low levels of yield associated with wheat production. Consequently, adoption of row and transplanting techniques could be quite beneficial in terms of enhancing the productivity and yield levels. Such planting technologies allow for reduced seed rate along with increased space between seedlings, which in turn has been seen to achieve important yield enhancement over backward sowing techniques. More importantly, the row planting technologies allow for better weeding, seedlings, branching out and nutrient uptake of wheat crop [9,10]. However, adoption rates have been generally low and quite slow particularly among wheat farmers. Besides, several aspects of adoption decision are poor despite their well-recognized role as a crucial route out of poverty in most less developed and developing countries [11,12]. Recommendations of the improved row planting technique was first introduced to 400,000 wheat grower farmers in selected 200 rural kebeles located in the four main wheat growing belt of Amhara, Oromia, Southern Nations Nationalities Peoples Region (SNNPR) and Tigray [3]. Row planting through a reduced-seed rate during sowing period is a major piece of the package in agricultural sector. However, smallholder farmers were not convinced that the recommended amount of 50 kg/ha seeds was enough since they broadcast used 150 kg/ha. Smallholder farm households who cultivate the agriculturally recommended amount of wheat crop seed have got impressive production [3].

In the study site too, the technology has been carried out through extension and rural development offices for many years. However, the effect of the sowing techniques is linked to major problems in implementation of the adoption decision and its policy implication, methodological issues, and over optimism of the potential of row cultivating in real farm agriculture [13]. The row sowing methods is seen as best agronomic techniques by agricultural plan designer, policy makers and extension personnel. However, there is little research evidence regarding the potential effect of the row planting on selected outcomes at farm level. In particular, the determinants of wheat row sowing methods and its impact on key household outcomes such as wheat cereal crop yield and expenditure among small-scale farmers has not been explored in detail. Their studies specifically, row wheat cultivating technology is significant on yield. Current study includes broader sets of outcomes at wheat grower level, specifically; focusing on measure of wheat grower wellbeing such as annual income and consumption expenditure. Particular, the study focuses on assessing the impact of row wheat cultivating technology on wheat grower food consumption expenditure which is key indicator of wheat grower food security. Adopters of row wheat growing technology are beneficiaries of the technology than counterparts. Row wheat cultivating technology enhances wheat grower's yield and annual income than non-adopter of wheat cultivating technology. Increase in yield and annual income of wheat grower is benefit of adopter and counterparts are affected.

Understanding of the factors underlying farmers' adoption decisions of agricultural technologies (such as row planting) is crucial in terms of achieving enhanced crop yield through improved adoption of such technologies. There is a growing body of literature focusing on determinants of and impact of farmers' choice of technological adoption [3,14-21]. In particular, numerous studies have been conducted focusing on the household and institutional aspects of adoption decisions and their impact. However, findings have often been mixed and at times conflicting [22]. Part of the literature has focused on specifically wheat cultivation [3,14,23]. However, with the exception [14] the rest focused on crop income as a measure of welfare, an obviously poor measure. Building on existing studies, we extend the analysis by considering a comprehensive set of welfare measures.

To this end, the current study was conducted to investigate the effect of sowing in row on wheat crop income, consumption expenditure and crop yield. Specifically, objectives of the study were to investigate factors that affecting row planting technology adoption decision in wheat cropping and evaluate its effect on household welfare and production-related outcomes such as income, consumption expenditure and crop yield in the study area.

2. Materials and methods

2.1 Description of the study area

This study was employed in Duna district, located in the SNNPR of Ethiopia. The total population of the district is 148,667, of which 75,483 (50.77%) is male and 73,183 (49.23%) is female. The total farmer in the district is 18,852, majority of which (18,209 (96.59%) is male. Agroecologically, the district is classified into three zones: Dega (80%), Weina Dega (14%) and kola (6%). The mean yearly rainfall ranges from 1510 mm to 1989 mm and has a mean annual temperature of 20^0c. The district receives low rains in March while high rains in July. Main production season is July and August during which all major cereal crops are grown. The elevation in the district varies from 2,969m asl to 1100m asl in the district. The total area of the district is 43,104 ha (222.57 square km), of which 30,172.8 ha (70%) is potentially cultivable. The relatively high population density of 619.58 per square km coupled with the high proportion of young population in the rural areas of the district exerts considerable pressure on farm land. Duna district was considered appropriate for the study for many reasons. First, it is one of the districts with high potential for wheat production. Second, it is one of the districts where row planting technology has been introduced and well under implementation for wheat crop yield. There is a strong extension intervention focusing on wheat crop growers. Moreover, newly introduced recommended wheat crop varieties and row sowing techniques were widely applied in the district.

2.2 Sampling technique

A multi-stage probability sampling method was employed to select the sample wheat grower. In the first stage: four wheat grower kebeles were randomly selected from wheat growing Kebeles in the district, based on their agro-ecology three of the kebeles (Mande, Kankicho, Bure) from Dega kebeles and the fourth one (Bada) from Weina Dega kebeles. In the second and final stage: total number of wheat growers (6020) were selected from a list of each selected wheat grower kebeles stratified by adoption status. A total sample size 375 wheat grower were selected from each stratum using proportionate sampling procedures. Finally, the sample respondents from four kebeles would be selected randomly by employing randomly sampling methods. Sample wheat grower was formulated based on the econometric formula given by [24]. Accordingly, a total of 375 farm households (161 participants and 214 non-participants) were selected for the survey during the 2018/19 wheat cropping season. Smallholder wheat cultivator is participant of row cultivating technology. Adoption is the change that takes place within wheat cultivator with regard to innovation from initial that wheat cultivator becomes aware of innovation to the final decision to use row cultivating techniques. It passes awareness of innovation, decision unit creation, attraction to seek innovation, put an innovation in to utilization and finally, innovation decision is made. Adopters are wheat cultivator in row by using recommended agricultural inputs and chemical fertilizers.

Table 1 Sample of wheat grower based on adoption status.

Kebeles	Total households (N_i)	Probability proportional sample (PPS) Size				
		Adopters		Non- adopters		Total sample
		N_a	n_a	N_{na}	n_{na}	(n_i)
Mande ($Kebele_1$)	1452	612	38	840	52	90
Kankicho ($Kebele_2$)	1511	648	40	863	54	94
Bure ($Kebele_3$)	1582	690	43	892	56	99
Bada ($Kebele_4$)	1475	641	40	834	52	92
Total	6020	2591	161	3429	214	375

Note: n_i= total sample from kebeles i (i = 1, 2, 3, 4); N_i= total households in kebeles i; N_a = Total number of adopters; N_{na}=Total number of non-adopters; n_a = adopting households selected; n_{na} = non-adopting households selected.

2.3 Types and sources of data

Descriptive statistics and econometric methods were employed for the data analysis. Primary and secondary data were used. Qualitative and quantitative of primary data were employed. The primary data collection was included wheat grower demographic, and socio - economic characteristics and adoption decision information. To get required primary data questionnaires, key informant interviews and focus group discussion were used. To address objectives of the study open and close ended questionnaires were prepared. The study was supplemented by secondary data obtained from published and unpublished documents, extension office, administrative office, relevant literature, website and other relevant organizations. Information obtained from secondary source includes list of rural wheat growers and non - growers. Furthermore, interviews were held with key informants. Cross - sectional field survey data was collected in the months between March and July 2018/19.

2.4 Method of data analysis

Data analysis was carried out using descriptive statistics and econometric methods. Descriptive analysis was examining demographic characteristics and socio-economic profiles of the wheat grower and performed using indicators such as frequency, averages, percentages, tables, stander deviation, maximum and minimum values, $\chi 2$ and t - test. Specifically, we use $\chi 2$ tests for evaluating associations between adoption status and qualitative factors such as gender of the head. Furthermore, t-test shall be used to check whether treated groups are different from control groups in terms of selected quantitative factors, thereby searching for potential relationships. Next, we applied econometric methods to provide a more appropriate and in-depth analysis. More specifically, we employ logit model for the purpose of exploring factors affecting the adoption of row planting techniques among wheat producing households. Besides, propensity score matching technique was employed to measure the effect of adoption of the technology.

Our estimation strategy was guided by the conceptual framework showed in Figure 1. Accordingly, households' decision to adopt agricultural technologies is affected by a number of factors. Demographic factors like sex, age, family size, and family labor; socio-economic factors like education status, livestock ownership, livestock holding and off - farm income; institutional factors like extension use, credit use, farmers training center, field day demonstration, distance to market, recommended agricultural inputs and fertilizer use are some of the factors documented in extant literature as key determinants that influence adoption of row planting. Adoption of row planting is crucial and in turn enhances farmers' crop productivity and hence increase farmers' crop income. The conceptual framework showed in the Figure 1 outlines the most crucial factors and the inter-relationship among them expected to affect the intensity of adoption decision of row planting wheat crops.

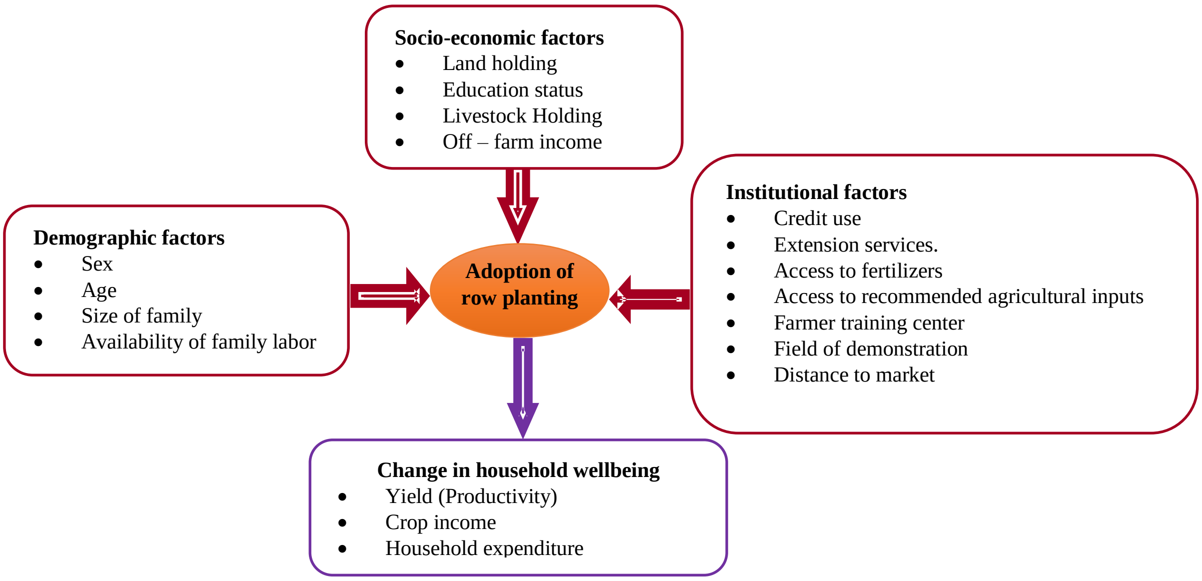

Figure 1 Conceptual framework (based on literature).

According to the previous studies [15,18,23] developed the research on row cultivating techniques were significant on yield. This indicated that participants of row wheat cultivating technology enhances yield than counterparts. Yield is the indicator variable for their studies, any change in yield brings change in household wellbeing. Current study focuses on examining the effect of row wheat sowing techniques on small holder farmer's food consumption expenditure which is key indicator of food security and wellbeing. Adoption of row wheat planting technology, food security and smallholder farmer's wellbeing are positively correlated. This reveals that any change on indicator variables such as wheat crop yield, annual income and smallholder farmer's expenditure brings change in household wellbeing.

$$ADOPT_i = \alpha + \boldsymbol{\beta} X_i + u_i \quad (1)$$

Where $ADOPT_i$ is the adoption status of household i, which takes score 1 for households who have adopted row planting technology in wheat production and 0 otherwise; X_i is vector of covariates including socioeconomic, demographic and institutional factors that are presumed to affect adoption status of household i (Table 2); u_i is the error term of the model such that $u_i \sim N(0, \sigma^2)$; and α, β are model parameters to be determined. Given our dependent variable is dichotomous; the probit and logit models are commonly employed techniques to estimate the technical specification given by equation (1). In this study, the logit model is employed for its simplicity and ease of interpretation of the parameter estimates in probability terms. Logit regression model with logistic probability distribution its simplicity calculation and probability lie between 1 and 0. It represents a close approximation to the cumulative normal distribution, mathematically easily used model and is easier to work with. For investigating the effect of adoption of cultivating techniques on household welfare – the main interest of our analysis – we employ the following three welfare outcome indicators at household level: (i) wheat crop yield, measured by the total amount of wheat crop production at the household level expressed in quintals per hectare of land; (ii) total annual household income, expressed in Ethiopian Birr (ETB); (iii) total household food consumption expenditure, expressed in Ethiopian Birr (ETB).

Table 2 List of explanatory variables used for the analysis.

S.NO	Variable name*	Variable type**	Variable description and its measurement***	Expected sign
1	Education status	Categorical dummy	Years school	+
2	Age	Continuous	In year	-
3	Size of family	Continuous	In number	+
4	Land holding	Continuous	Hectares	+
5	Livestock holding	Continuous	TLU	+
6	Access to extension service	Dummy	If 1 = Yes and 0 = otherwise	+/-
7	Availability of farm labor	Dummy	If 1 = Yes and 0 = otherwise	+/-
8	Access to credit service	Dummy	If 1 = Yes and 0 = otherwise	+/-
9	Sex	Dummy	If 1 = Male and 0 = Female	+/-
10	Use of recommended agriculture inputs	Dummy	If 1 = Male and 0 = Female	+/-
11	Off- farm income	Continuous	Birr per year	+
12	Quantity of fertilizer used	Continuous	Kg/ha	+
13	Farmers training center	Dummy	In number	+
14	Field day demonstration	Dummy	If 1 = demonstration and 0 = otherwise	+
15	Distance to market	Continuous	Km	-

Source: Authors hypothesis 2018/19.
*Dependent variable, adoption of row planting technology, explanatory variable and education status.** Binary.*** If 1 = adopter and 0 = otherwise.

Family size, education status, land holding, livestock ownership, use of extension and credit were expected positively in the current developed study. These positive expectations of the variables are in line with [23] developed study in row wheat cultivating techniques. The regression results of previous research indicated that there is positive correlation of the above listed variables and row wheat cultivating technology.

To assess whether adoption status is associated with differences in household level welfare outcomes, the following regression specification may be employed.

$$Y_i = \alpha + \gamma ADOPT_i + \boldsymbol{\beta} X_i + \xi_i \quad (2)$$

Where Y is a measure of household welfare; γ is the parameter of interest for estimating the effect of adoption; ξ is the model error term and the rest of the definitions are as in (1).

A major methodological challenge associated with the estimation of model (2) through the usual least-square procedure is that the parameter γ would typically be biased - a situation commonly referred to as 'self-selection' bias [25]. This is mainly because households' decision to adopt the planting technique is likely not random and that such decisions could be systematically related to other factors that affect household welfare outcomes. Besides, there are also unobservable differences between the two groups of households. The implication is that the two groups are not comparable, and that any difference between the two in terms of welfare cannot be attributed to differences in adoption status alone. Consequently, measurement of impact based on γ fails to separate the effect of adoption (i.e., treatment effect) from that attributable to systematic differences (i.e., selection bias). To address this challenge, we employ propensity score matching combined with a sensitivity analysis that tests the assumption of selection on observables [26]. The idea of propensity score matching is to show a comparison group that is based on a model of the probability of adopting in the treatment - also known as propensity score matching - using observed characteristics and then match participants to non-participants on the basis of this probability of participating. The average treatment effect is then determined as the average difference in outcomes across these treated and control groups. The validity of propensity score matching depends on two important conditions: (i) conditional independence (i.e., the assumption that unobserved factors do not influence adoption); and (ii) a sizable common support or overlap region in propensity scores matching across the treatment and control groups.

The fulfillment of the propensity score matching conditional independence characteristics needs that given observable covariates, potential findings are not dependent of adopters assignment [27]. This entails that the assignment to adopter and control groups is depends on observable variables, this is a strong characteristic to make. The overlap propensity scores matching condition, on the other hand, checks that adopter respondents have comparison respondents nearby in the propensity score matching distribution. The effectiveness of propensity score matching also not independents on having a very large and roughly equal number of adopter and control respondents so that a basic region of overlap can be found [28].

Accordingly, we estimate the ATE of adoption of wheat row planting technique on all outcome measures mentioned earlier. For this, we first estimated the propensity scores, using a logit model specified in equation (1). Only variables that are not possibly influenced by adoption status were included for the estimation. We then matched households using four of the matching algorithms: the nearest neighbor matching (NN), radius matching (RM), caliper matching (CM) and kernel matching (KM) [29]. We then estimated the ATE as the average weighted difference in findings between adopters and matched non-adopters using bootstrapped standard errors. To ensure the validity of the common support, we used observations in the common support region only and deleted all other observations whose propensity score was lower than that of the minimum for treated and higher than that of the maximum for the controlled [29]. To determine the best matching algorithm, we employed performance criteria such as balancing test of covariate means on the matched samples using t-tests. Furthermore, we also tested the balancing properties by estimating the propensity score matching on the matched sample and performing a likelihood ratio test on the together significant effect of all regressor. Accordingly, lower Pseudo R^2 from the re-estimation of the PS and significance of the LR test indicated fulfillment of the balancing properties.

Finally, to ensure the validity the conditional independence assumption, we conducted a sensitivity analysis as a means of checking for the robustness of our results. The idea is to check whether unobserved factors affecting both the treatment and the measured outcomes thereby resulting in a 'hidden/selection bias'. This was accomplished by checking the degree to which the estimated adopters' effect is sensitive to lower changes in the formulation of the propensity score matching. To confirm the robustness of the finding of the average treatment effect on the treated; the post estimation analysis of sensitivity test was checked. Sensitivity analysis examines how strong the influences of γ (unobserved) on the participation process need to be. If there are unobserved variable that affect assignment in to treat and the outcome variable simultaneously a hidden bias might arise to which matching estimators are not robust. It evaluates how program effect is affected by change in γ. If the analysis is free of hidden bias γ is zero. This sensitivity analysis is in line with sensitivity analysis of [16,20,23].

3. Results and discussion

3.1 Descriptive analysis

Table 3 presents summary statistics of the wheat grower by type of wheat planting technique (i.e., adoption status). About 42.93% of the total farm households practiced row planting technique, which was relatively smaller than those who didn't during the 2018/2019 cropping season.

Table 3 Sample farm households by adoption status.

Agricultural technology adoption	Frequency	Percent	Cumm. percent
Traditional planting methods	214	57.07	57.07
Row planting methods	161	42.93	100
Total	375	100	

Source: Own survey 2018/2019.

Based on responses open-ended questions put to respondents, lack of personal interest, un-suitability of cultivated land due to logging water, shortage of labor force, and the time-consuming nature of the row-planting technique were among the reasons cited for not practicing row planting technology. In fact, some of the respondents went to the extent of suggesting the need for government to consider distributing of row planting machine as a means to substitute for labor force deficits and shorten planting time.

In Table 4, we present summary statistics (i.e., means and standard deviations) for the major explanatory variables by adoption status. Also reported are the t-test and chi-square comparisons of means of these variables across the two categories of farmers. Accordingly, most of the sampled households were headed by males (70%), who are relatively older (about 57 years of age), literate (54% of whom attained primary level schooling or above), and support larger family (5.42) on average. Majority of the households are endowed with sufficient family labor (70%), own 10.7 units of livestock (in TLU) and cultivate 2.39 hectares of land on average. An estimated 63% of the households have access to extension services, 50% had used credit and 53% followed recommended agricultural inputs. According to cultivator 8011.375 Birr per year of non – farm income, 70.25 kg/ha utilization of fertilizer and 62.5% training center had on average. As estimated on average 55.6% of field day demonstration followed by 3.67 km distance to market center.

Table 4 Household characteristics (means) by adoption status.

Variables	Total Sample	Adopters	Non-adopters	Comparison [a]	*P*-value
Household welfare indicators					
Consumption expenditure (ETB)	13,389.99	16,558.33	8949.58	-4.325	0.000***
Annual income (ETB)	13,364.72	16,967.19	8603.78	-6.677	0.000***
Wheat crop yield (Quintal/year)	12.08	14.55	8.04	-6.143	0.000***
Household Characteristics					
Sex of the head (1 = male)	70.1%	72.5%	68.2%	0.399	0.528
Access to extension (1 = yes)	63.1%	82.5%	48.6%	22.596	0.000***
Use of credit services (1 = yes)	50.3%	65.0%	39.3%	12.139	0.000***
Availability of labor (1 = yes)	70.0%	75.0%	66.4%	1.631	0.202
Recommended inputs (1= yes)	53.5%	56.3%	51.4%	0.433	0.511
Head's education (1 = literate)	54.0%	89.0%	28.0%	32.37	0.000***
Age of the head (years)	56.8	53.0	59.6	32.158	0.807
Family size (number)	5.42	6.00	5.00	46.697	0.000***
Size of cultivated land (ha)	2.39	2.54	2.27	33.502	0.000***
Livestock possession (TLU)	10.66	11.87	9.77	49.199	0.000***
Off – farm income	8011.375	9472.50	6750.25	2722	0.000***
Quantity of fertilizer used	70.25	82.64	53.20	29.44	0.000***
Farmers training center	62.5%	81.9%	49.4%	0.325	0.000***
Field day demonstration	55.6%	58.4%	50.5%	0.079	0.624
Distance to market	3.675	2.525	4.687	-2.162	-5.423
Observations	375	161	214		

Source: Computed from own survey data 2018/19. [a] *t-values* for continuous explanatory variables; Pearson's $\chi 2$ values for categorical/dummy explanatory variables. Figures in parentheses are standard errors. *** $P < 0.01$.

Moreover, important differences were observed among adopters and non-adopters in terms of household characteristics. Accordingly, adopters had better educated heads than those of non-adopters, suggesting that education might be possitively correlated with adoption decision. Similarly, adopters had significantly larger family size than non-adopters. Besides, adopters cultivated larger farmlands and owned more livestock units than their non-adopter counterparts indicating the importance of household asset ownership in adoption decisions. The two groups also significanty differed in terms of access to institutional services where adopters had better access to extension, farmers training center and credit services on average than their non-adopting counterparts. Regarding to off – farm income and quantity of fertilizer utilization adopter on average better than their non adopting couterparts. However, there was no statisically sinificant variation in terms of age and gender of the heads suggesting the lack of association between household demographics and adoption decisions. Lastly, there was no difference in terms of use of recommended level of agricultural inputs, field day demonistration, availability of farm labor and distance to market between adopters and non-adopters. Adopters have better formal education, large family size, large cultivated farm land, more livestock ownership, better extension and credit services, better farmers trianing, larger off – farm income and better chemical fertilizer utilization are positively correlated with row cultivating technology on average than non adopters. Any better change in the above listed variable, brings better change adopters wheat crop yield and annual income than non adopters.

3.2 Econometric results

Model estimates for the determinants of household decisions to adopt the row planting technology are presented in (Table 5). The goodness fit with regard to the predictive efficiency was high with 317 (84.53%) of the 375 wheat grower respondents included in the model perfectly predicted.

Table 5 Estimates of the determinants of households' adoption decisions (n = 375).

Variable	Coef.	SE [a]	Z	P >|Z|	dy/dx [c]
Age	-0.0457***	0.026	-2.92	0.004	-0.021
Sex	0.126	0.436	0.27	0.789	0.029
Size of family	0.329**	0.154	2.31	0.032	0.073
Education status	0.695**	0.371	2.36	0.014	0.265
Land holding	0.988*	0.556	1.82	0.062	0.250
Livestock holding	0.240*	0.172	1.93	0.031	0.233
Credit used	0.927**	0.415	2.16	0.014	0.235
Recommended agricultural input	0.543	0.379	1.41	0.263	0.138
Availability of family labor	0.273	0.445	0.28	0.713	0.141
Extension services	1.040***	0.382	2.73	0.006	0.276
Off – farm income	0.289**	0.101	1.08	0.038	0.140
Quantity of fertilizer used	1.115***	0.453	2.05	0.002	0.342
Farmers training center	0.504***	0.266	2.29	0.000	0.224
Field day demonstration	0.348	0.285	2.47	0.285	0.154
Distance to market	-0.876	0.452	-1.78	0.658	0.276
Constant term	-6.697	1.859	-3.60	0.000	-
LR chi2 (15)	60.75	Pseudo R2			0.345
Prob > chi2	0.000	Log likelihood			-85.038

Source: Computed from own survey data 2018/19; [a] robust std. errs. [b], ***, **and * are 1%, 5% and 10% statistically significant levels respectively.

Accordingly, ten of the fifteen variables included (head's age, head's schooling, family size, cultivated land size, livestock ownership, off - farm income, quantity of fertilizer utilization, farmers training center, credit use, and extension services) were found to have significant association with the level of practicing row cultivating technology. Specifically, age was found to have a strong negative association with adoption decisions. Keeping other factors fixed, each extra year of the head's age is expected to result in a 2.1% reduction in the probability of adoption, a statistically significant association ($P < 0.01$). Put differently, households whose heads are on average 10 years older are expected to be 21% less likely to adopt row planting than their younger counterpart, which is quite significant.

On the other hand, factors such as level of education of the household head, size of family, land holding, livestock ownership, off - farm income, quantity of fertilizer utilization, farmers training center, access to credit service and access to extension use had all significant positive associations with households' adoption decisions, with marginal effects ranging between 7.3% to 34.2% on average (ceteris paribus). More specifically, an extra unit of head's education, family size, size of cultivated land, livestock possession in TLU, off - farm income, quantity of fertilizer utilization and farmers training center were respectively associated with a 26.5%, 7.3%, 25%, 23.5%, 14%, 34.2% and 22.4% higher probabilities of adoption on average, all else remaining the same. Moreover, households with access to credit and extension services found to be 22.5% and 27.6% higher probabilities of adopting row wheat crop sowing techniques respectively compared to those without access to these services. However, male headship, availability of farm labor, field day demonstration, distance to market and use of agricultural inputs as per recommendation by extension agents didn't have any significant association with adoption. The results from the econometric analysis presented in Table 5 were qualitatively similar to those of the descriptive statistics results presented in Table 4 except for that of age of household heads for which no significant difference was detected in the descriptive analysis while a negative association was found from the econometric estimates. Logistic regression result of current study is similar with the results of [16,20] developed research on row cultivating technology.

Accordingly, the common support region is estimated, on the (Table 6), below the estimated propensity scores matching varies between 0.1562118 and 0.9583230 for participants and 0.0321540 and 0.8483742 for non-participants. Accordingly, the common support of propensity score matching region was found in the range of 0.1562118 to 0.8483742 by discarding 5 wheat growers from those participants.

Table 6 Predicted common support of propensity score matching region.

Agricultural technology adoption	Mean	Std. Dev.	Min.	Max.
Traditional planting methods	0.3589210	0.3566077	0.0321540	0.8483742
Row planting methods	0.7913368	0.3552772	0.1562118	0.9583230
Total	0.5376833	0.4365730	0.0321540	0.9583230

Source: Own survey 2018/2019.

Propensity score matching algorithm can be selected based on balancing test, low Pseudo R-square, large matched sample size and insignificant LR chi-square. From four used matching algorithms: nearest neighbor matching (NNM), radius matching (RM), caliper matching CM, and kernel matching (KM); a nearest neighbor matching 4 was best estimator of the outcomes of the study. since it resulted in the least Pseudo R- square 0.012, a large number of matched sample size 370, LR Chi2 = 2.35 and P = 0.892 by deleting 5 adopters from 375 of households (Table 7).

Table 7 Selection of matching algorithm.

Matching algorithm		Before matching			After matching		
		Pseudo R2	LR Chi2	P - value	Pseudo R2	LR Chi2	P – value
NN	1	0.345	85.28	0.000	0.047	7.94	0.846
	2	0.345	85.28	0.000	0.019	6.12	0.812
	3	0.345	85.28	0.000	0.024	5.54	0.776
	4	0.345	85.28	0.000	0.012	2.35	0.892
	5	0.345	85.28	0.000	0.028	6.06	0.820
KM	(0.1)	0.345	85.28	0.000	0.027	5.84	0.838
	(0.25)	0.345	85.28	0.000	0.028	6.20	0.373
	(0.5)	0.345	85.28	0.000	0.062	13.52	0.001
RM	(0.01)	0.345	85.28	0.000	0.337	54.88	0.000
	(0.1)	0.345	85.28	0.000	0.337	54.88	0.000
	(0.25)	0.345	85.28	0.000	0.337	54.88	0.000
Caliper	(0.1)	0.345	85.28	0.000	0.036	7.94	0.846
	(0.25)	0.345	85.28	0.000	0.036	7.94	0.846
	(0.5)	0.345	85.28	0.000	0.036	7.94	0.846

Source: Own computation 2018/2019.

Table 8 reports the estimated treatment effects from the propensity score matching. We find that row wheat crop planting techniques had significant effect on wheat growing farmer welfare as evidenced by the significantly larger per capita consumption expenditure and annual income resulting from adoption ($p < 0.01$).

Table 8 The average treatment effect.

Findings	Adopters	Non - adopters	Difference	BSE	T-stat
Wheat yield (Qt/ha)	14.55	7.32	7.25	0.92	3.55^{***}
Income (ETB)	16,967.19	8,786.45	8,180.74	1,109.52	3.46^{***}
Consumption expenditure (ETB)	16,558.33	9,212.41	7,345.92	1.587.78	3.25^{***}

Source: Computed from own survey data 2018/19, *** $P < 0.01$.

More specifically, the food consumption expenditure of adopting farmers was much higher than those who didn't adopt on average by 7,345.92 ETB. The annual consumption expenditure for the sample shows considerable variation with a minimum of 4000 ETB for the poorest household and a maximum of 87000 ETB for the richest household. Given the mean level of annual consumption expenditure of about 6337 ETB for the poorest quartile of households in the study area, the estimated ATT translates into roughly doubling of the consumption level for this poorest section of the population in the area. This is quite a significant welfare effect. Similar findings have been reported by [14] for Southeastern Ethiopia.

Similarly, the income of adopters was also found to be significantly higher than those of their non-adopter counterparts by 8,180.74 ETB on overage. Compared to the mean annual income in the area reported to be 13,364.72 (see Table 4) the estimated effect is quite substantial as it translates into nearly a 60% of increment in the annual incomes in the study area. This finding confirms earlier findings of [16, 20] where adoption of technology (improved variety and row planting) resulted in significant income improvement for teff crop farm households in Ethiopia.

On the other hand, the results also show that row planting technology had significant effect on wheat yield at 1% significance level ($p < 0.01$) during the 2018/19 cropping season as has been the case for [3,14,23] for Ethiopia; and [15] for Ghana. The average yields of wheat crop of adopters were higher by 7.23 quintals per hectare compared with the mean productions of control groups. This is quite a substantial yield improvement considering the mean wheat yield in the study area was 12.08 quintals/ha (Table 4), which represents nearly a 75% increment on average.

These findings indicate that adoption of modern planting technique (row planting) had in deed a significant positive impact on households' welfare. In particular, adoption was associated with significantly higher consumption expenditure, increased annual income, and higher crop yield. Hence, participation of row wheat crop cultivating had a positive effect on the life of the treated showing positive welfare impact or alleviation of poverty level on the side of the treated. Average treatment effect on the treated results of current study is similar with the results of [16,20] developed research on row cultivating technology. According to their studies yield and annual crop net income of row cultivating technology adopters are greater than non-adopters. According to regression result consumption expenditure is most important result among yield and annual income. From consumption expenditure, food consumption expenditure is a key indicator of wheat grower wellbeing than crop yield and annual income.

3.3 Sensitivity analysis

Sensitivity analysis is the final diagnostic that must be done to analysis the sensitivity of the estimated treated group effect to small variations in the specification of the model. Sensitivity cheek is a highly strong evaluating assumption and must be justified. The Q_mh+ and Q_mh- are statistical balance for positive and negative unobserved selection on the impact of row sowing techniques. Both Q_mh+ and Q_mh- give the similar findings on the impact of cultivating wheat crop in row on wheat grower income, consumption expenditure and crop yield. We conclude based on this concept of sensitivity analysis that the findings are not affected by external effect. This shows that the treatment effect on the treated is not sensitive to any external variation. In generally, the results revealed that there is no hidden bias. This study finding is similar with the study’s findings of [16,20,23] conducted research on row wheat cultivating technology. Their study’s sensitivity analysis results revealed that average treatment effect on the treated is not sensitive to external change. Hence, there are no external variables which affect the result determined for average treatment effect on the treated.

Table 9 Sensitivity check.

Gamma	Q_mh+	Q_mh-	*P*-value	*P*-value
1	.	.	.	.
1.05	-.094055	-.094055	.537467	.537467
1.1	.	-.094055	.	.537467
1.15	-.094055	-.094055	.537467	.537467
1.2	.	-.094055	.	.537467
1.25	-.094055	-.094055	.537467	.537467
1.3	-.094055	-.094055	.537467	.537467
1.35	-.094055	-.094055	.537467	.537467
1.4	-.094055	.	.537467	.
1.45	.	-.094055	.	.537467
1.5	-.094055	-.094055	.537467	.537467

Source: Source: Own computation 2018/2019.

4. Conclusion

This study was focused on investigating the determinants of row planting technology adoption and impact of technology adoption decision on household welfare among wheat growers in Duna district, Ethiopia. The study was used primary and secondary source of the data. Primary data were collected from interview questionnaires, key informant interviews and focused group discussion. Descriptive and econometric techniques were applied as the methods of data analysis. Particularly, propensity score matching model was applied to evaluate treated groups with control groups in terms of income, consumption expenditure and crop yield. Among four matching algorithms nearest neighborhood matching method 4 was best estimator of the outcome variables.

The findings revealed that adoption decision of row wheat crop farming technique was associated with significant improvements in household welfare as reflected in significantly increased household consumption per capita expenditure and net annual incomes. We also find that adoption is associated with higher yields per hectare among wheat producing farm households. The sensitivity cheek also revealed that predicts are almost free from unobserved covariates or bias. Consequently, it can be determined that the overall the findings are remarkably robust supporting the robustness of the matching techniques.

Moreover, key household characteristics such as the age, education status, size of family, off - farm income, size of cultivated land and livestock holding; and institutional factors such as use of credit, use of extension services, use of quantity of fertilizer and farmers training center were found to be important factors underlying households’ adoption decisions. More specifically, adopters were found to be younger, more educated, had larger family, had higher off - farm income, cultivated larger farmlands and owned more livestock units than their non-adopter counterparts. Access to institutional services such as use of credit, use extension services, use of quantity of fertilizer and use of farmers training center were also important drivers of adoption decision. However, there was insignificant effect of gender, use of recommended level of agricultural inputs, avaliabilty of family labor, field day demonistration and distance to market adoption decisions. The proponsity score matching technuques of teated groups were higher by 7.23 quintals of yiel per haectar, 8,180.74 ETB annual income and 7,345.92 ETB food consumption expenditure than that of controlling groups in the planting season. Therefore, agriculture and rural devlopment office, extension service office, microfinance office and another concerned body should give an imprortant attention to row cultivating technology which is key indicator to alliviate poverty.

5. Acknowledgements

The authors would like to extend their gratitude to farmers who participated in the survey and Duna District Agriculture and Natural Resource Development Office and staffs there for the secondary data and unreserved support they provided to the study.

6. References

[1] Hill R, Eyasu T. Ethiopia poverty assessment. [Final report]. Washingtong, DC: Poverty Global Practice Africa Region, World Bank Group; 2015.

[2] Abraham B, Araya H, Berhe T, Edwards S, Gujja B, Khadka RB, et al. The system of crop intensification: reports from the field on improving agricultural production, food security, and resilience to climate change for multiple crops. Agric Food Secur. 2014;3(1):4.

[3] Abate GT, Bernard T, Brauw A, Minot N. The impact of the use of new technologies on farmers' wheat yield in Ethiopia: evidence from a randomized control trial. Agric Econ. 2018;49(4):409-421.

[4] Beyene LM, Legesse EE. Public investment in irrigation and training for agriculture-led development: a CGE approach for Ethiopia. SSRN Electron J. 2013;2:1-78.

[5] ATA Ethiopia [Internet]. Addis Ababa: The Agency; c2010. [cited 2019 Oct 15]. Results of 2012 New Tef Technology Demonstration Trials. Available from: http://sri.cals.cornell.edu/aboutsri/othercrops/teff /Ethiopi a_SCI_tef_2012_trials.pdf.

[6] Central Statistics Agency [Internet]. Addis Ababa: The Agency; c1963. [cited 2019 Oct 15]. Area and production of major crops. Available from: https://www.statsethiopia.gov.et/wp-content/uploads/2019/06 Agricultural-Sample-Survey-Area-and-Production-Meher-Season-2013.pdf.

[7] FAO [Internet]. Rome: The Organization; c1945. [cited 2019 Oct 15]. Feeding the world in 2050. Available from: http://www.fao.org/tempref/docrep/fao/meeting/018/k6021e.pdf.

[8] Rashid S. Staple food prices in Ethiopia. RePEc. 2010;1:2-13.

[9] Jabbar MA, Saleem MA, S, Erkossa T. Technical and economic performance of animal-drawn implements for minimum tillage: experience on vertisols in Ethiopia. Exp Agric. 2002;38(2):185-196.

[10] Chauhan BS, Abeysekera AS, Wickramarathe MS, Kulatunga SD, Wickrama UB. Effect of rice establishment methods on weedy rice infestation and grain yield of cultivated rice (*O. Sativa L.*) in Sri Lanka. Crop Prot. 2014;55:42-49.

[11] Bandiera O, Rasul I. Social networks and technology adoption in northern Mozambique. Econ J. 2006;116(514):869-902.

[12] Simtowe F, Berresaw MK, Diagne A, Silim S, Muange E, Asfaw S, et al. Determinants of agricultural technology adoption: the case of improved pigeonpea varieties in Tanzania. Q J Int Agric. 2011;50(4):325-345.

[13] Vandercasteelen J, Dereje M, Mart MM, Seyoum TA. The impact of the promotion of row planting on farmers' teff yields in Ethiopia. Econ. 2013;344:3-27.

[14] Mulugeta T, Hundie B. Impacts of adoption of improved wheat technologies on households' food consumption in southeastern Ethiopia. In: Bernard L, editor. International Association of Agricultural Economists (IAAE) Triennial Conference; 2012 Aug 18-24; Foz do Iguaçu, Brazil. Boston: Wiley-Blackwell; 2012. p. 2-13

[15] Akudugu MA, Guo E, Dadzie SK: Adoption of modern agricultural production technologies by farm households in Ghana: what factors influence their decisions. Int J Agric Biol. 2012; 2(3):1-13.

[16] Yonas B. The impact of row planting of teff crop on rural Household income: a case of Tahtay Maychew wereda, Tigrai, Ethiopia. Econ. 2015;1:9-58.

[17] Awotide BA, Diagne A, Omonona BT. Impact of improved agricultural technology adoption on sustainable rice productivity and rural farmers' welfare in Nigeria: a local average treatment effect (LATE) technique. Business. 2012;1:2-23

[18] Kasirye I. Constraints to agricultural technology adoption in Uganda: evidence from the 2005/06-2009/10 Uganda national panel survey. African J Agric Resour Econ. 2013;8(2):1-18.

[19] Abebe B, Workayehu T. Effect of method of sowing on yield and yield components of Tef (Eragrostis Tef (Zucc) trotter) at Shebedino, southern Ethiopia. Glob J Chem. 2015;2(1):37-44.

[20] Duressa D. Analysis of factors influencing adoption of Quncho Tef: the case of Wayu Tuqa district. Int J Afr Asian Stud. 2015;12:1-10.

[21] Gebregewergs EYaB: Effect of wheat row planting technology adoption on small farms yield in Ofla Woreda, Ethiopia. Int J Agric Extension Social Dev.2016:3(5):184-196.

[22] Rauniyar GP, Goode FM. Technology adoption on small farms. World Dev. 1992;20(2):275-282.

[23] Alemu T, Emana B, Haji J, Legesse B. Impact of wheat row planting on yield of smallholders in Arsi zone of Ethiopia. IJEER. 2014;4(5):386-393.

[24] Yamane T. Statistics: an introductory analysis. 3rd ed. New York: Happer & Row publisher;1973.

[25] Wooldridge JM. Introductory econometrics: a modern approach 5th ed. Ohio: South-Western publisher; 2013.

[26] Rosembaum P, Rubin D.B. The central role of propensity scores in estimating dose-response functions. Biometrika. 1983;70(1):41-55.

[27] Imbens GW. Nonparametric estimation of average treatment effects under exogeneity: a review. Rev Econ Stat. 2004;86(1):4-29.

[28] Khandker SR, Koolwal GB, Samad HA. Handbook on impact evaluation quantitative methods and practices. [Internet]. New York: The World Bank; 1944 [cited 2019 Jun 15]. Available from: http://documents1.worldbaank.org/curated/en/650951468335456749/pdf/520990PUB0EPI1101Official0Use0Only1.pdf.

[29] Caliendo M, Kopeinig SS. Some practical guidance for the implementation of propensity score matching. J Econ Surv. 2008;22(1):31-72.