Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research

Vol. 11, Issue, 05, pp. 46617-46620, May, 2021

https://doi.org/10.37118/ijdr.21479.05.2021

ISSN: 2230-9926

RESEARCH ARTICLE

OPEN ACCESS

IMPACT OF IRRIGATION ON GRAIN MAIZE PRODUCTIVITY IN ETHIOPIA

***Tesfaye Haregewoin**

Ethiopian Agricultural Research Council Secretariat

ARTICLE INFO

Article History:

Received 19th February, 2021
Received in revised form
10th March, 2021
Accepted 20th April, 2021
Published online 14th May, 2021

Key Words:

Impact, Irrigation, Productivity, Grain Maize, Ethiopia

****Corresponding author:***
Tesfaye Haregewoin

ABSTRACT

One of the sources that contribute to food shortage is poor productivity levels. This study examines the impact of employing irrigation on grain maize productivity using 350 sample farm households in Ethiopia. Propensity score matching technique was employed since it is one of the most common and increasingly utilized standard methods for evaluating impacts using observational data. And the study found that irrigators enjoy a positive and significantly higher productivity, on the average from 42-45% higher, than their counterparts, non-users. Thus, the study recommends that use of irrigation could be an effective strategy to enhance productivity and, thereby, production that contributes a lot to the improvement of the livelihood of grain maize producing farm households.

Citation: ***Tesfaye Haregewoin.* 2021.** "Impact of irrigation on grain maize productivity in Ethiopia"*, International Journal of Development Research*, 11, (05), 46617-46620.

INTRODUÇÃO

In the Ethiopian economy, agriculture has been and still is the mainstay of the economy (MoA, 2010). It supplies 70% of outputs to export earnings, covers 80% of employment opportunities, and contributes about 40.2% to the GDP (UNDP, 2015). Owing to the undependable rainfall, persistent drought, and limited capacity of utilizing existing water resources, Ethiopia's agriculture sector in particular and its economy, in general, have been negatively affected. The erratic nature of the rainfall has claimed over one-third of the growth potential of the country's economy and in effect, it has been estimated a 25% rise in the poverty rate in the economy (World Bank, 2006). Though the agriculture sector's contributions in the economy, as well as livelihood improvement of smallholder farmers, has been so immense, it has remained in its infancy stage due to backward and limited agricultural technologies, traditional ways of cultivations, recurrent drought, and the like (CSA, 2012; MoFED, 2012). To overcome the interlocking challenges in the sector, adapting to irrigation agricultures or technologies as coping mechanisms are crucial steps in increasing production and productivity (MOA, 2011; Haile and Kasa 2015). Numerous studies have revealed that irrigation agricultures have had positive and considerable impacts on increasing agricultural production, productivity and livelihood improvement of smallholder farmers by increasing their income (Abraham *et al*., 2015; Astatike, 2016; Gebrehiwot *et al*., 2017). Moreover, employing irrigation techniques helps play a pivotal role in stabilizing agricultural outputs, increasing production and cropping intensity, and alleviating the adverse impacts of erratic or inadequate rainfall (Awulachew *et al*., 2010; Getaneh, 2011). Giving due attention to irrigation developments and thereby enhancing traditional and modern irrigation technologies have been found essential mechanisms to encourage sustainable economic and rural development, boost agricultural yields and revenues, and ultimately helps secure food security and promotes poverty reduction (World Bank, 2006; MoWR, 2002; MOFED, 2006). First, maize was originated in North America, especially in the United States of America. It ranks third among the most important food crops produced next to rice in the world and stands second after cassava in Africa and also grown in a varied environment. Originally, it was introduced to Ethiopia around the last quarter of the 16th century. Since then, it has been the most important staple food. It ranks first in total grain production and second in areal coverage among cereals and is widely grown by smallholder farmers in Ethiopia (Kpotor, 2012 and FAO, 2014). Among the many cereal crops produced in Ethiopian agriculture, maize is the leading and most important food grain next to wheat. It is widely grown from lowlands to highlands and plays important role in the efforts to maintain food self-sufficiency. However, its production and productivity have adversely been affected by recurrent drought and scarcity of water as it is very susceptible to water stress (Payero *et al*., 2008; Robel *et al*., 2018). Under normal circumstances, the impact of irrigation on grain maize yield or productivity has a positive correlation with the amount of irrigated water, irrigated land, and irrigation techniques applied in grain maize agriculture (Mintesinot *et al.,* 2004; Tsedeke, *et al*., 2015; Tagheinaghdam *et al*., 2015*)*. Maize cultivated areas and maize production and productivity in Ethiopia have gone up by twofold since the early 1990s. These substantial changes in maize production and productivity have been achieved through adopting traditional and modern farming techniques, innovations and by encouraging extension services. Even though dramatic changes and transformations have been recorded in maize production and productivity increment over the years, still there are many works to be done to harness the unutilized opportunities to greatly boost the yields in quality and quantity (Tsedeke, *et al*., 2015). According to data availed by CSA in 2013/2014 indicated that in Ethiopia more maize was produced than any other cereals and it was largely grown by smallholder farmers. In the same year, the total volume of maize produced amounted to 42 million qt. which was 40% and 75% higher than teff and wheat production respectively and the average yield was found to be 17.4 qt. per hectare. Hence, maize has been the leading most important cereal crop produced since the 1990s in case of production and productivity (Rashid *et al*.; 2010).

Analytical framework for evaluation of irrigation impact on grain maize productivity

One of the main challenges in undertaking a trustworthy impact evaluation is the construction of the counterfactual outcome, that is, what would have happened to participants without treatment. To this end, the counterfactual outcome has to be estimated using statistical and econometric methods because this counterfactual outcome is never observed. And constructing the counter factual outcome using propensity score matching technique is becoming an increasingly employed approach. Propensity score matching technique uses information from a pool of households that do not participate in theint ervention to identify what would have happened to participating households without the intervention. Pairing treatment households and households in the control group with similar observable characteristics is the general idea of propensity score matching technique. Matching methods can yield an unbiased estimate of the treatment impact when the relevant differences between any two units arecaptured in the observable pretreatment covariates, which occurs when outcomes are independent of assignment to treatment conditional on pretreatment covariates (Cochran and Rubin, 1973 and Rosenbaum and Rubin,1985). In Propensity score matching, it is assumed that data can be obtained for a set of potential control units, for whom the same set of pretreatment covariates, Xi, is observed but that are not necessarily drawn from the same population as the treated units. If for each unit we observe a vector of covariates Xi and $y_{i0}\perp Ti|Xi$, ∀i, then the population treatment effect for the treated,$\tau|_{T=1}$, is equal to the treatment effect conditional on covariates and on assignment to treatment$\tau|_{T=1,X}$, averaged over the distribution$X|T_i = 1$(Rubin, 1977). Matching units on their vector of covariates, Xi, estimates this equation. Rosenbaum and Rubin (1983) suggest the use of the probability of receiving treatment conditional on covariates. Accordingly the probability of receiving treatment conditional on covariates is expressed as: let $p(X_i)$ be the probability of a unit i having been assigned to a treatment defined as:

$p(X_i) \equiv \Pr(T_i = 1|X_i) = E(T_i|X_i)$, then

$(Y_{i1}, Y_{i0}) \perp T_i|X_i\, f\, (Y_{i1}, Y_{i0}) \perp T_i|p(X_i)$

Heckman, Ichimura, and Todd (1998), suggested the following to determine or compute the treatment effect:

$$\hat{\tau}|_{T=1} = \frac{1}{|N|}\sum_{i\epsilon N}\left(Y_i - \frac{1}{|J_i|}\sum_{j\epsilon J_i} Y_i\right)$$

where N is the treatment group, |N| the number of units in the treatment group, J_i is the set of comparison units matched to treatment unit i and $|J_i|$ is the number of comparison units in J_i.

DATA

The data utilized for this study is acquired from farm house hold survey under taken during 2015/16 by Ethiopian Institute of Agricultural Research (EIAR) in collaboration with the International Fund for Agricultural Development (IFAD). A total of 1,531farmhouseholds from 4 Administrative Regions; namely, Tigray, Amhara, Oromia and SNNPR, 18 “woredas” (districts) and 20 ‘Kebeles’ (villages/localcouncils) in Ethiopia were interviewed. Out of which 350farm households were grain maize producers.A Two-stage Random Sampling method wasemployed, and the primary sampling was carried out to select ‘Kebeles’ from project intervention areas while the secondary sampling was undertaken to select sample households from selected‘ Kebeles’. The data wascollected using a pre-tested interview schedule by trained andexperiencedenu merators who speak the local language and have good knowledge of the farming systems.

RESULTS AND DISCUSSIONS

Descriptive Statistics: Table 1 below displays various variables that describe the major observed characteristics of the sample respondents included in the propensity score matching model. The grain maize productivities of irrigation users and non-users are respectively 3.86 ton and 2.3 ton. Thus, it tentatively shows that there is significant difference in productivity level between those households that utilize irrigation and those that do not. Households that do not use irrigation possess larger landholding size than those farm households that use irrigation as irrigators are technology intensive to compensate for the lower total grain maize production by raising productivity level. Those farm households that travelled shorter distance to the local market were more likely to use irrigation since households far from the market incur high marketing and transportation cost. Over and above, irrigators used larger amount of pesticide and labor than those households that did not use irrigation.

Treatment Effects Estimation using a Probit Model: Attributing the change in productivity of grain maize to utilization of irrigation without using rigorous impact evaluationtechnique leads to invalid inferences since the difference in productivity might be owingto other determining factors. To this end, a rigorous impactevaluation method; namely, Propensity Score Matching isemployed to control for observed characteristics and determinethe actual attributable impact of irrigation use on grain maize productivity in Ethiopia.

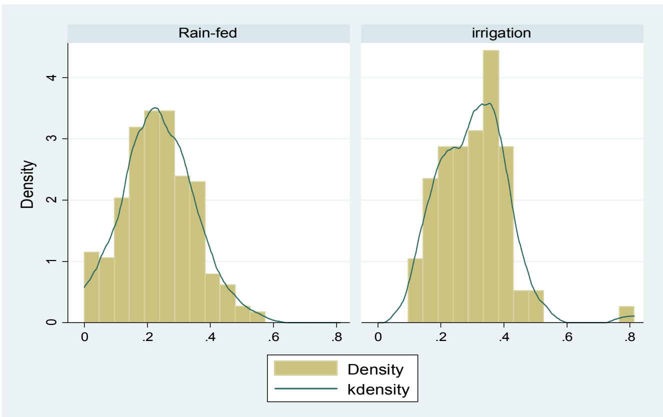

Fig. 1. Estimated propensity scores

A probit model is used to estimate Propensity scoresfor both who utilize irrigation and non-users to compare the treatment group with the control group. Figure 1 shows the visualpresentation of the distributions of the propensity scores.The probit model calculates each observation’s propensity scores, and the propensity score for those who utilize irrigation rangesbetween 0.1050704and 0.8136591 while it ranges between2.67e-23and 0.5676373for those who do not use irrigation. And the region ofcommon support for the distribution of estimated propensityscores of irrigation users and non-users ranges between 0.10507043 and 0.5676373. Observations whose propensityscore lies outside this range were discardedwhen matchingtechniques are employed. Moreover, Figure 2 shows that thecommon support condition is satisfied as indicated by thedensity distributions of the estimated propensity scores for thetreatment and control groups as there is substantial overlap inthe distribution of the propensity scores of both those who use irrigation andnon-users. Test of balancing property of the propensityscore also indicated that the balancing property is satisfied. use of irrigation significantly increases grain maize productivity by 42 percent while Nearest Neighbor Matching and Kernel-basedmatching techniquerespectively convey that use of irrigation even more substantially increases grain maize productivity by 44 and 45 percent for farmhouseholds in the study area.

Table 1: Descriptive statistics of important variables used in the probit model-Propensity Score Matching

Variables	Unit	Irrigation Users Mean(se)	Non-users Mean(se)	Aggregate Mean(se)	t-stat.
Outcome variable					
Productivity	#	3855.684(465.44)	2272.73(228.04)	2673.478 (210.31)	-3.33***
Variables that affect probability of using irrigation					
HHAGE	#	45.90 (0.81)	46.33(1.10)	46.01(.67)	0.28
HHEDU	#	2.26 (0.18)	2.09(0.29)	2.22(0.15)	-0.49
LANDSIZE	#	1.20(0.07)	1.52(0.07)	1.44(0.06)	2.45***
CHEMFERT	#	13.28(1.92)	12.19(1.64)	12.46(1.31)	-0.36
PESTCIDE	#	4.52(1.56)	0.56(0.40)	3.52(1.17)	-1.47*
LABORCOST	#	57.65(15.66)	14.13(5.74)	46.63(11.83)	-1.60*
PRODASSET	#	1.31(0.05)	1.25(0.08)	1.30(0.04)	-0.554
DIST2MARKT	#	98.41(4.06)	120.39(6.26)	103.97(3.46)	2.79***
IMPROVEDSEED	1=Yes	0.41(0.06)	0.34(0.03)	0.36(0.03)	-1.11

***, **, * indicate significance at 1 percent, 5 percent and 10 percent level respectively.
Source: Own computation, 2021

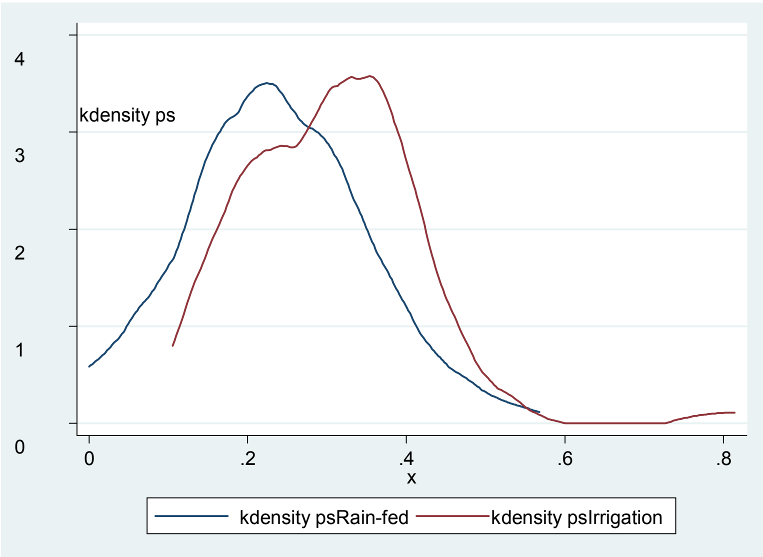

Fig. 2. Distribution of propensity scores of irrigation and rain-fed cultivators

Table 2. Average Treatment Effect estimation with Nearest Neighbour Matching Estimator

Outcome Variable	ATT	Std. Err.	z	P>|z|	[95% Conf. Interval]	
lnproductivity	0.437	0.162	2.69***	0.007	0.1189133	0.7556869

Table 3. Average Treatment Effect estimation with Stratification method

Outcome Variable	ATT	Std. Err.	t-stat.
lnproductivity	0.421	0.112	3.777***

Table 4. Average Treatment Effect estimation with Kernel Matching method

Outcome Variable	ATT	Std. Err.	t-stat.
lnproductivity	0.451	0.107	4.199***

Significance levels (*, **, *** denoting significance level at 10%, 5% and 1% respectively)
Source: Own computation, 2021

Meanwhile, Nearest Neighbor matching technique, Stratification matchingtechnique, and Kernel-basedmatching technique were employed in the estimation of average treatment effects to check for robustness of the various estimates. The following tables report the estimates of the average effectsof irrigation use on grain maize productivity estimated by Nearest Neighbor matching technique, Stratification matchingtechnique, and Kernel-basedmatching technique. Accordingly, Stratification matchingtechnique tells that

Conclusion and Recommendation

The ultimate purpose of this study is to identify the attributable impact tousing irrigation on grain maize productivity in Ethiopia and, hence, put forward a recommendation. The study used propensity score matching technique which is one of the most commonly used impact evaluation technique. It also employed and compared various matching algorithms; namely, Nearest Neighbor matching, Stratification matching, and Kernel-based matching to ensure the robustness of impact estimates. Finally, it is concluded that employing irrigation enabled farm households that adopted it to enjoyhigher and significantly positive productivity than their counterparts, the non-irrigators. This indicates that irrigation has anenormous potential in reinforcing the agricultural extension system that targets increasing production and productivity. Therefore, this study recommends toextensivelyencourage farmers to employ irrigation in all grain maize producing areas of the country, and it should be accompanied by increasing availability of affordable irrigation schemes for the smallholder farmers to enhance their livelihood.

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