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Analysis of Technical Efficiency of Small Scale Irrigation Technologies in Two Selected Areas of Amhara Region, Ethiopia

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Abstract

The paper provides a comparative analysis of Technical efficiencies of two household irrigation technologies; rope and washer and pulley practiced by farmers in two pilot areas of rural communities in Amhara region of Ethiopia. The paper attempted to identify factors that contribute to the inefficiencies in using these technologies for the production of irrigated crops. Stochastic Frontier Analysis (SFA) was used for estimating the efficiency levels and the ordinal regression analysis has been employed to factor out determinants of inefficiency. Experimental data has been used from two selected communities in two different districts of the Amhara region. The results obtained from the stochastic frontier analysis indicate that farmers are operating at a significantly lower efficiency level of average 70% indicating the existence of a room for increased production without additional investment. A number of socioeconomic, demographic and farm characteristics were identified as factors contributing to the inefficiency which can be used as a policy tool to boost production to the best possible.

Keywords: Stochastic frontier analysis; Small-scale irrigation; Technical efficiency

Introduction

Since agriculture is the main source of income and employment, the economic growth and poverty status in Ethiopia reflects the performance of the agriculture sector. On the other hand, the production system is constrained by low and erratic rainfall causing low input use and low agricultural productivity. Hence, investment in irrigation as a strategy to reduce the negative effect of rainfall variability and low input use has received momentum since recently [1].

The fact that this sector is heavily dependent on rainfall and very limited use of improved farming technologies makes the country to stay underdeveloped and puts the nation's food security endanger. At times when the country is hit by drought, it has a devastating consequence resulting in famine and the loss of life. Irrigation can significantly improve the productivity of agriculture and hedges it from climate variability related shocks.

Despite the large water resources, Ethiopia continues to receive food aid to about 10% of the population who are at risk annually [2]. Droughts have frequently affected the lives and livelihoods of rural populations as well as the national economy.

In sub-Saharan Africa, only 4% of the agricultural land is irrigated. Although an estimated 40 million ha are suitable for irrigation, only 7.3 million ha are actually irrigated and the vast majority of this irrigated land is concentrated in just four countries: Madagascar, Nigeria, South Africa, and Sudan [3].

Small-scale irrigation has additional benefits in narrowing income disparity, providing better nutritional outcome and advancing rural development and prosperity. Privately managed household level irrigation, in particular, has higher productivity and profit margins, because private ownership and operation of technologies avoid problems related with collective action often observed in public or communal irrigation schemes; studies from sub-Saharan Africa, for example in Zimbabwe [4-6]. The authors documented that private irrigation technologies allow smallholder farmers to adjust irrigation schedules to respond to localized events and are more likely to bring higher returns per hectare than community managed irrigation schemes [7-9].

A number of reasons could explain the significantly low practice of irrigation while drought is expected to happen right at the spot tomorrow. In addition to policy, poverty, and so on related issues inefficiency could be one factor that hinders Ethiopian farmers to put irrigation as an option to cop up drought and famine. One possible strategy to address this problem could be looking for the best way of using resources for maximum output.

This study investigates the level of technical efficiency of household irrigation technologies (Rope and washer and pulley) that are used to produce vegetable and irrigated fodder and then identifies factors that contribute to the inefficiency of the technologies under consideration.

The literature on production or technical efficiency in African agriculture is emerging. Globally, there is a wide body of empirical evidence on the economic efficiency of farmers both in the developed and developing countries. While the empirical literature on the efficiency of farmers is vast in developed countries and Asian economies, few studies focus on African agriculture.

To our knowledge, empirical evidence on the technical efficiency of household level irrigation technologies is scant in Ethiopia. Exceptions are have been made on irrigation schemes in general [10-16].

Seyoum et al. [10] investigate the technical efficiency and productivity of maize producers in Ethiopia and compare the performance of farmers within and outside the Sasakawa-Global 2000 project demonstration. Using Cobb-Douglas stochastic production functions, their empirical results show that farmers that participate in the program are more technically efficient with mean technical

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efficiency equal to 94% compared with those outside the project with mean efficiency equal to 79%.

For potato producing farmers of Awi zone-Ethiopia, Bogale and Bogale [11] found that the efficiency levels are fairly better 77% and 97% for modern and traditional irrigation schemes, respectively. Using the stochastic production frontier approach, Kelemework [12] analysed the Awash River basin farmers data and conclude that the existing irrigation systems are not that efficient (55.5% for Doni and Godino, 76% for Batu Degaga and 79.8% for dry land farmers) and indicated the need to make them operate near their production frontier.

Gebregziabher et al. [13] made a comparative efficiency analysis, using the data from smallholder farmers in the Tigray region of Ethiopia, between irrigated and rain-fed agriculture and showed that irrigated agriculture suffers from severe inefficiency problem as low as 45% though it provides better revenue as compared to the rain-fed agriculture. In a study made to assess the productivity of maize production in southern Ethiopia observed the level of efficiency to be as low as 40% [14].

Given the current state of technology the author Yami argued that it is possible to increase wheat production by 45% for some selected water logged areas of Ethiopian farmers in the Oromia region [15]. Kitila and Alemu analysed the data from smallholder maize producing farmers of the Oromia region of Ethiopia and estimated technical efficiency that ranges from 0.06 to 0.92 with a mean technical efficiency of 0.66 (66%) [16].

Despite the common belief about the benefits of schooling in farm activities, there is weak empirical evidence to advocate educational investment in agrarian societies. The existing studies on the determinants of farm productivity and efficiency are largely inconclusive on the question of a positive return to education. Using data in maize producing farmers of eastern Ethiopia confirmed the positive relationship between efficiency and years of schooling [10]. On the other hand, the authors fail to identify any significant impact of farmers' education on farming efficiency in India, and Java-Indonesia, respectively and whereas Yami and Kitila found a negative and statistically significant coefficient for education in the efficiency model using data in the Oromia region of Ethiopia [15-18].

Findings by FAO-2008 on women in Agriculture shows that women make up over half of the agriculture labour force yet they are frequently subjected to discrimination, poverty and hunger. Women allocate their work time and manage risk differently than do men for a number of reasons. Some of these include the unique child-rearing responsibilities of women, and the result of cultural gender roles and differences in access to agricultural productive resources. In many countries, family roles, responsibilities, and rights are gender related and extend beyond biological differences. As a result of all these factors it is natural for someone to expect gender differentials in technical efficiency. Simonyan et al. found a significant technical efficiency differential between male (93%) and female (98%) maize producing farmers in Nigeria [19]. On the other hand using random sample of rice producing farmers in Ghana Addison et al. found that male headed households are found to have higher technical efficiency than their female counterparts [20].

Foster and Rosenzweig used panel data and a model incorporating supervision costs, risks, credit market imperfections and scale economies associated with mechanization, reported that small-scale farming is inefficient in India [21]. In a study for identifying factors affecting the efficiency of maize producing farmers in the southern Ethiopia found farm size and use of improved seed variety carrying a positive and significant coefficient [14].

Taking into account all the many dimensions whereby efficiency is affected, the focus of this paper is to measure technical efficiency of household level irrigation technologies and the factors that contribute to the inefficiencies it there is any. Specifically, it analyses the technical efficiency of two water lifting technologies; Pulley and Rope and washer pumps used in two selected areas of the Amhara region to produce Tomato, Onion, and Fodder.

Methodology

Study area and data

This study is based on data drawn from the two research sites of the Feed the Future (FtF) Innovation Laboratory for Small-Scale Irrigation (ILSSI) in Ethiopia. These include Robit-Bata and Dangila in Amhara region (Figure 1).

Dangila is one of the Agricultural Growth Program (AGP) and USAID Feed the Future woredas in the Amhara regional state. It is located about 80 kilometers southwest of Bahir Dar. In the Woreda, there are 27 rural Kebeles among which 16 of them have access to perennial rivers. Average annual rainfall is about 1600 mm but varies between 1180-2000 mm. The mean annual potential evapotranspiration (PET) is 1250 mm. Monthly PET during November to April exceeds monthly rainfall implying the importance of dry season irrigation Robit-Bata is one of the rural kebeles in Bahir-Dar Zuria woreda of Amhara regional state. It is located 10 km north of Bahir Dar. Bahir Dar zuria woreda is also one of AGP and Feed the Future woredas in the region. It has a sub-tropical ("Woina Dega") climate. The livelihood system is based on cereal and high value irrigated crop production. Groundwater potential and experience in smallholder irrigation is relatively high. Motor pumps together with manual water lifting devices are widely used in the kebele. Shallow groundwater, river diversion, and lake pumping are the main sources of irrigation water. In the year of 2014, about 1820 ha. of land was irrigated, in which 85% are by using motor

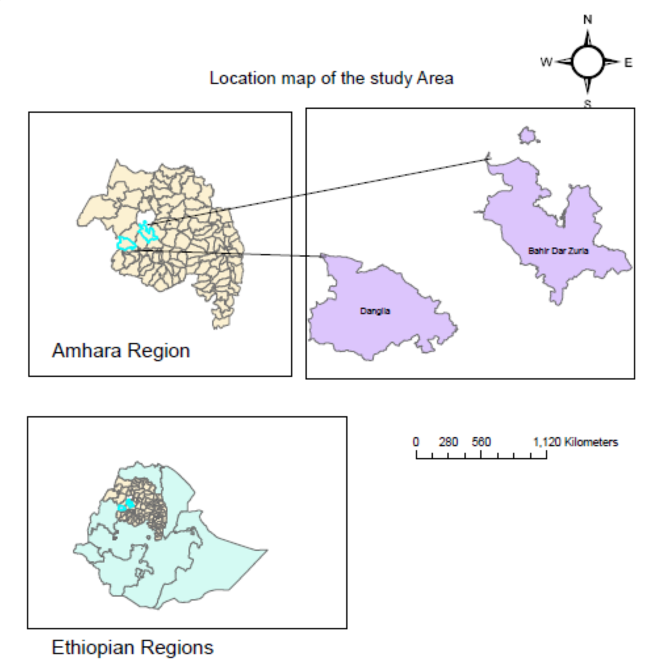

Figure 1: Map of the study area.

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pumps, there are about 4000 individual wells in the kebele.

From the above two purposely selected areas, 54 target households were selected by the local administrators and community leaders of the respected areas within the areas whose farms reside on specified watersheds. For this target households (22 from dangishita kebele and 32 from Robit-Bata kebele) two irrigation technologies (Rope-and-Washer and Pulley) were made available on credit basis with which they cultivated a common crop (Tomato and elephant grass in Robit and onion in Dangishita) during the 2014/2015 dry season. 33 percent of the farms under the experiment are owned by female household heads.

The irrigated farms were allowed to run on different plot sizes ranging from 50-meter squares to 250-meter squares. These farms enjoyed a close follow up of different agricultural professionals. Training was also provided that includes land and nursery preparation, plant spacing, fertilizer application, irrigation scheduling, financial literacy and so on.

A number of data collection instruments were employed. Before the intervention, a baseline data was collected using a semi-structured questioner and focus group discussions. It is used to capture information about the socioeconomic, demographic and agronomic practice of the household and family members. The field book which is used to collect data related to agronomic practices and related costs have helped us a lot in capturing necessary information. Throughout the production season, the researchers were very close to the farmers to monitor the experiment that has given them a chance to observe and understand the characteristics of the farmers and farming practices, that otherwise could necessitate focus group discussions and key informants interviews. This paper takes 54 farmers for its analysis.

Analytical framework

The stochastic frontier model: Aigner et al. For the first time, related the concept of efficiency to the production frontier four decades ago [22,23]. The production frontier defines the technical efficiency in terms of a minimum set of inputs in order to produce a given output or a maximum output produced by a given set of inputs. The stochastic frontier production function models were first introduced by authors, who is more realistic and in line with the economic theory than the so-called average production function. This model assumes that the disturbance term, in the general production function model given below, has two components. That is

$$\varepsilon_i = v_i + u_i$$

$$y_i = f(x;\beta) + \epsilon_i \quad (1)$$

$$y_i = f(x; \quad) + v_i - u_i \quad (2)$$

Where $v \sim N(0,\ \delta_v^2)$ *and* $u \sim N_+$ and y is the amount of output units produced using x input units and β is the parameters to be estimated.

The error component v_i represents the symmetrical disturbance that captures random errors caused outside the firm's control such as measurement errors, random shock, and statistical noise. This component is assumed to be identically and independently distributed as $v \sim N(0,\ \delta_v^2)$.

The u_i component of the error term is the asymmetrical term that captures the technical inefficiency of the observations and assumed to be independent of v_i and also satisfy that $u_{i>}0$. The non-negative component (u_i) reflects that the output of each firm must be located on or below its frontier [24]. If u=0 the firm is 100% efficient, and, if u>0, then there is some inefficiency. Knowing the range of values that the inefficiency term takes on is not enough. Battese and Broca stress the need to make some statistical assumptions on the pattern of the values of this term [24]. The assumption of which distributions the u_i's are following can be picked for a variety of reasons, such as ease of use, ease of estimation, level of skewness, number of the parameters, etc. Half-Normal, Truncated Normal, Exponential, and the Gamma are among the most commonly assumed distributions.

The central element of the Stochastic Frontier Analysis models rests on the degree of asymmetry of the error term, ϵ_i which is the convolution of the two components, v and u in the model. And since we have already made a statistical assumption on the pattern of the normal term v, the observed pattern of ϵ_i, will tell us the pattern of u. The degree of asymmetry can be represented by the following parameter:

$$\lambda = \frac{\sigma_u}{\sigma_v} \quad (3)$$

The larger λ is, the more pronounced the asymmetry will be. On the other hand, if λ is close to zero, then the symmetric error component dominates the one-side error component in the determination of ϵ_i. Therefore, the complete error term is explained more by the random disturbance v_i than by u_i, which follows a normal distribution. ϵ_i therefore has a normal distribution.

To estimate the stochastic frontier analysis models, that is, to determine the values of the unknown parameters β, σ_v^2 *and* σ_u^2 the maximum likelihood principle is used. That is, we estimated the parameter values as the values that make the observations as likely as possible. To do so, however, we must know the density of the combined error term $\epsilon_i = v_i + u_i$

When the model is estimated to find β, σ_v^2 *and* σ_u^2, the error term can easily be calculated as

$$\epsilon_i = v_i - u_i = y_i - f\left(x_i;\hat{\beta}\right) \quad (4)$$

So far, we have focused on the estimation of the functional form and whether the deviations from the production function can be decomposed into noise and inefficiency. We have not, however, analysed the efficiency of individual firms, which, after all, is a major concern. Let us now turn into how firm-specific efficiency can be estimated. Technical efficiency is measured as the ratio of actual production to potential production. Using the models in the stochastic frontier analysis it can be written as;

$$TE_i = \frac{Actual\ Production}{Potential\ Production} = \frac{f(x_i;\beta) + v_i - u_i}{f(x_i;\beta) + v_i} \quad (5)$$

Where all the variables are in logarithmic form. If it is raised to e and simplifying it, we will get;

$$TE_i = \frac{e^{f(x_i;\beta)+v_i-u_i}}{e^{f(x_i;\beta)+v_i}}$$

$$TE_i = e^{-u_i} \quad (6)$$

The above equation requires us to get an estimate of u_i for each farm in the sample. And this needs a bit more mathematical manipulation as it is not directly observed from the model. Rather it is embedded in the combined error term.

The estimate of ϵ_i does carry some information about u_i. If $\epsilon_i>0$, then chances are that u_i is not very large, as E (v_i)=0, suggesting that technology i is relatively efficient. If, on the other hand, $\epsilon_i<0$, then u_i

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will tend to be large, suggesting that technology *i* is relatively inefficient. This tells us that the estimate of the (unobserved) efficiency term, u_i depends on the (observed) error term ϵ_i.

We will, therefore, look at the conditional distribution of u_i given ϵ_i and use the conditional expectation $E(u_i/\epsilon_i)$ as an estimator of u_i.

The joint density of v_i and u_i is the product of the individual densities, as they are independent

$$f_{v,u}(v,u) = f_v(v)\, f_u(u) \tag{7}$$

Substituting ϵ+u for v we get

$$f_{\epsilon,u}(\epsilon,u) = f_v(\epsilon+u)\, f_u(u) \tag{8}$$

Therefore, using Bayes' theorem, the conditional density of u given ϵ is;

$$f(u/\epsilon) = \frac{f_v(\epsilon+u)\, f_u(u)}{f_\epsilon(\epsilon)} \tag{9}$$

Here recall that the functional forms $f_v(v)$, $f_u(u)$ *and* $f_\epsilon(\epsilon)$ are as assumed at the beginning. That is they are, respectively distributed as Normal, Half Normal and the Convolution of the two. Using this assumption and after some algebraic manipulation one can arrive at

$$E(u/\epsilon) = \mu_* + \sigma_* \frac{\varnothing(\mu_*/\sigma_*)}{\Phi(\mu_*/\sigma_*)} \tag{10}$$

Where $\mu_* = -\epsilon\frac{\sigma_u^2}{\sigma^2} = -\epsilon\frac{\lambda^2}{1+\lambda^2} = -\epsilon\gamma$ and $\sigma_* = \sqrt{\frac{\sigma_u^2\sigma_v^2}{\sigma^2}} = \sigma\frac{\lambda}{1+\lambda^2} = \sqrt{\gamma(1-\gamma)\sigma^2}$

and $\phi(.)$ is the density function, and $\Phi(.)$ the cumulative distribution function of a standard normal distribution. When we substitute the estimated values for ϵ, σ^2 and λ then we have an estimate of u conditioned on the estimate of ϵ. We, thus now get an estimate of TE.

Results and Discussion

Descriptive results

Data used in this study came from the two sites in Robit-Bata and Dengeshita both in Amara region of Ethiopia where the two household irrigation technologies (i.e., pulley and Rope and Washer) were implemented (Table 1).

	Robit-Bata	Dengeshita	Total
Pulley	20	11	31
Rope & washer	12	11	23
Total		32	77

Table 1: Distribution of technologies.

The variables of interest are presented in the summary statistics table. The experimental plot where the crop is cultivated was as small as 135-meter squares on average. It was not only because it is difficult to find farmers, who have a larger size of plots next to their water source to provide for our experiment, but it was also because of the projects' experimental design Tomato, onion and Napier grasses for livestock feed were the cultivated irrigated crops during the dry irrigation season. The yield obtained varies by sites, gender, the water-lifting technology used and type of cultivated crop. A hybrid seed has been used for tomato cultivation and local seed for onion. Since the hybrid seed is cheaper, the total cost is observed to be lower for tomato producers (2077 Birr /hectare) than onion producers (8505 Birr/hectare).

An important socioeconomic variable which affects not only efficiency in production but also the lives of individuals and society's well-being is education. As is the case in the rural areas of the country, the educational attainment level of the farmers under the experiment is as low as 2 years of schooling on average. About 84% of the Robit farmers and 50% of Dangishita farmers are illiterate. Dangishita beneficiaries are relatively better educated having an average of about 5 years of schooling (Figure 2).

Farmers who cultivated onion produced not only much below the standard yield, 200 quintals/hectare (FAO), level but also less than those who chose to cultivate tomato. This is most likely attributed to the fact that onion producing farmers had no any irrigation experience as compared to the other group who had been using irrigation for the last decade. The lower education level observed has also played its role in making them unable to invest their scarce resources in a way that they can achieve the maximum attainable production (Table 2).

The labour to yield ratio observed is much higher than was required in the standard agronomic requirement of the crop comparing it to the tomato crop. It seems that Onion producing farmers used their technology, labour and other resources unwisely.

The estimates of the efficiency term are computed based on definition presented above. The results from the SFA model indicate that there are farmers who are suffering from inefficiency levels as low as 51%. It is easily seen that production can be doubled for some farmers though the average technical efficiency level is about 70% (Figure 3).

The efficiency estimate result indicates the existence of a significant room for improvement by about 30%. Before looking into advancements in technology it pays for us to manage resources in a way that can provide us a significant amount of production. From the literature reviewed in is not surprising to see farmers who are at a very

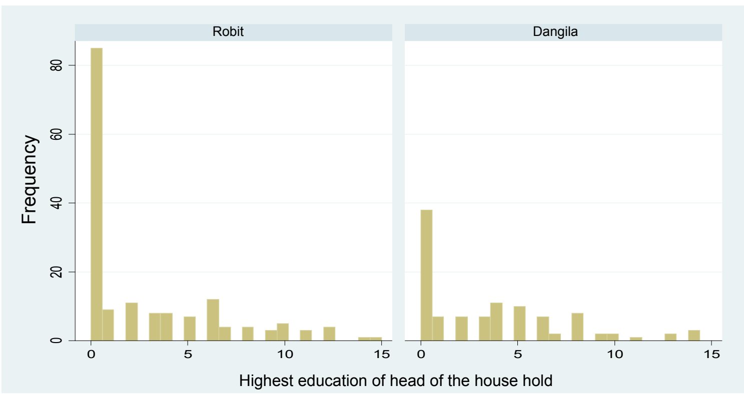

Figure 2: Education level of head of the household in the experiment.

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	Mean	St. Dev.	Minimum	Maximum	N
Yield (KG/Hectare)	10,771.23	11,476.02	-	62,160.00	77
Cost of oxen labor (birr/Hectare)	16.09	8.11	-	39.96	77
Cost of fertilizer (birr/Hectare)	0.32	0.23	0.01	0.90	54
Cost of seed (birr/Hectare)	5,507.19	2,939.16	1,500.00	10,000.00	54
Area of land in hectare	0.01358	0.00450	0.005	0.0272	54
Labor (man-day/Hectare)	1,597.80	1,042.52	309.07	6,200.00	54
Average Price of land per hectare	2,796.30	247.98	2,500.00	3,000.00	54
Livestock Holding	5.14	3.26	0.10	16.12	54
Land holding	1.38	0.82	0.25	3.25	54
Age of household head	42.04	11.83	18	65	54
Education of household head	1.85	3.24	0	12	54

N: Normal

Table 2: Summary statistics.

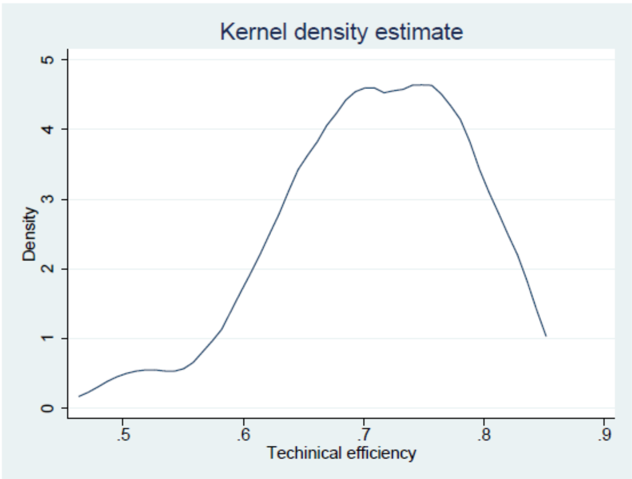

Figure 3: Kernel density of technical efficiency.

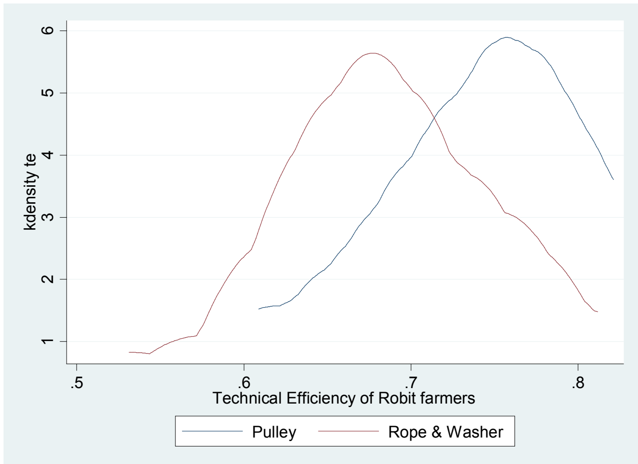

Figure 4: Technical efficiency of pulley vs. Rope & Washer.

lower efficiency level in the rural community. It has been argued by many researchers that inefficiency is an inherent problem and cannot be removed completely (Figure 4).

For Rope-and-washer users, the severity of inefficiency is relatively higher than farmers who chose to use a pulley. This could be due to the intensive labour and technical skill requirement of the technology. This problem is even more severe for robit farmers probably because of the opportunity cost of labour is higher (Tables 3 and 4). Farmers in Dangishita apply their labour expecting the benefits of the additional income from irrigation which they never or very rarely do it before (Tables 5 and 6).

Both women and men headed households in the study area generally appear to have no difference in efficiency levels (Table 4). But when looked at disaggregated based on the type of crop cultivated and different experimental sites, lower efficiency level are observed for women headed households (Tables 7 and 8). An average of 76% efficiency level is recorded for women headed households who are engaged in the production of fodder as compared to only 70% for their male headed fodder farmers.

Regression results

The ordered logit model (proportional odds model) result indicated that inefficiency in using the two water lifting technologies is due to a number of socioeconomic and demographic variables. Table 9 shows the coefficients of the regression output and the odds ratio for the variable included in the model. The odds of being at a higher efficiency level is increased by about 13% for male-headed households and married household found to have 1.2 times more odds of being at a high-efficiency level as compared to non-married farmers in the involved in the project (Table 9).

	Mean	St. dev.	Min	Max	N
Female	0.76	0.03	0.73	0.80	5
Male	0.70	0.05	0.62	0.81	10
Total	0.72	0.05	0.62	0.80	15

St. dev.: Standard Deviation; N: Normal

Table 3: Efficiency for fodder.

	Mean	St. dev.	Min	Max	N
Female	0.70	0.07	0.53	0.81	18
Male	0.70	0.08	0.49	0.82	36
Total	0.70	0.08	0.49	0.82	54

St. dev.: Standard Deviation; N: Normal

Table 4: Efficiency of all samples.

	Mean	St. dev.	Min	Max	N
Female	0.68	0.07	0.53	0.81	13
Male	0.71	0.08	0.49	0.82	26
Total	0.7	0.08	0.49	0.82	39

St. dev.: Standard Deviation; N: Normal

Table 5: Efficiency for vegetable farmers.

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	Mean	St. dev.	Min	Max	N
Female	0.70	0.08	0.53	0.8	10
Male	0.72	0.06	0.61	0.82	22
Total	0.71	0.07	0.53	0.82	32

St. dev.: Standard Deviation; N: Normal

Table 6: Efficiency of Robit farmers by gender.

	Mean	St. dev.	Min	Max	N
Pulley	0.73	0.06	0.6	0.82	20
R&W	0.68	0.07	0.53	0.81	12
Total	0.71	0.07	0.53	0.82	32

St. dev.: Standard Deviation; N: Normal

Table 7: Efficiency of Robit Farmers by technology.

	Mean	St. dev.	Min	Max	N
Pulley	0.65	0.07	0.49	0.74	11
R&W	0.73	0.06	0.6	0.81	11
Total	0.69	0.08	0.49	0.81	22

St. dev.: Standard Deviation; N: Normal

Table 8: Efficiency of Dangila farmers.

Variables	Coefficients	Odds ratio	P-value
Family size	0.00864	1.009	0.002
Education of household head	0.0546	1.056	0.031
Age of household head	0.005	1.004	0.049
Crop type cultivated	0.17	1.180	0.042
Type of irrigation technology installed	0.18	1.200	0.005
Size of plot allotted for the experiment	0.005	1.000	0.002
Sex of household head	0.128	1.140	0.002
Distance from market	0.0318	1.030	0.044
Marital status of household head	0.169	1.180	0.120
Non-farm income in 2014	0.00000527	1.000	0.049
Cut1	-0.887		
Cut2	1.281		

Table 9: Ordered logit results.

The choice of technology also matters for the level of technical efficiency. All the farmers in Robit Bata kebele who took rope and washer were dissatisfied and had discontinued to use them probably due to the depth of water and high level of labour requirement. Labour is very expensive in Robit as compared to Dangishita most likely due to the proximity of Robit to Bahir-Dar city where employment opportunity is relatively high resulted in high demand for labour and high daily wage rate. This implies that a blanket recommendation of technology adoption is not appropriate implying that "one does not fit all". Hence, identifying and choosing appropriate technology that is suitable to a particular environment is important and can have paramount importance towards improving efficiency in production and hence the lives of farmers.

Age of the household head was one of the variables considered in estimating the level of technical efficiency. It is believed that age can serve as a proxy for farming experience. The expected age was found to have positive and significant (at 5% level of significance) effect on the level of technical efficiency of smallholder farmers.

Education which serves as a proxy for managerial skills was found to have positive and significant (at 5% of significance level) effect implying that a higher level of education may lead to higher efficiency due their ability to better manage their farms including efficient use of inputs and ability to respond to unforeseen shocks. In addition, education enhances a farmer's ability to make good use of information about extension package and farming in general. As the result of intensive support provided by the project the impact of education and the levels of income they got from farm activities seem to have economically significant effects on the efficiency levels.

Conclusion

The paper utilized experimental data to analyse the technical efficiency of smallholder farmers who adopt household irrigation technologies to produce irrigated vegetables and fodder. our findings indicate that rope and washer users are less efficient as compared to pulley users probably attributed to a wide range of factors, such as the difference in labour use, knowledge, the experience of producing using the technology, agro ecology, etc. The result further indicated that efficiency varies across the combinations of gender, crop type cultivated and water lifting technology employed.

This relatively high inefficiency may arise from adoption-related problems. Water lifting technologies under study are new to most of the farmers and dry season irrigation is a recent experience in the study areas.

It should be noted that inefficiency is a loss for a producer. Being unable to produce to the level potentially possible is something that should take attention first. This may be done through providing a continuous capacity building to farmers for better allocation of their scarcer resource and labour time. The option of producing at least twice a year would also contribute to reducing the loss resulted from inefficiency. Second, extension support in identifying the right mix of crops and technology may improve the production and productivity of farmers. Moreover, farmers with less irrigation experience can increase their productivity if they can acquire the skill from experienced farmers. This can be continuously coordinated by local development agents.

Finally it should be emphasized that only few researches have been done in measuring efficiency of small holder farmers. For the right policy action it requires to dig out additional findings that range at various ecological conditions, societal segments, etc.

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