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Full Length Research Paper

Technical efficiency in irrigated small-scale agriculture: Empirical evidence from onion farming in Kobo District of Northeast Ethiopia

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The purpose of this study is to understand the extent and determinants of smallholders' technical efficiency under drip and furrow irrigation in dry land agriculture. Stochastic production frontier model with Cobb-Douglas functional form was fitted to a random sample of drip and furrow irrigated plots to understand farmers' technical efficiencies in onion production. The study was based on cross-sectional data collected from 200 farm households during the 2012 production year; 100 households from each type of irrigation schemes. The test result indicated that there was technical inefficiency in both irrigation schemes and the relative deviation from the frontier due to inefficiency which was about 26.31%. The estimated mean level of technical efficiency of the traditional diversion furrow and modern drip irrigation scheme users were about 78.60 and 82.59%, respectively. The overall mean technical efficiency of the irrigation schemes was 73.69% which indicated that the improvement in technical efficiency was still possible with the current available technology and without increasing the input level. The result also revealed that land related factors such as land size, land ownership, and land fragmentation explain much of the technical inefficiencies in addition to other socio-economic characteristics of farm households. Total land size is inversely related to the technical efficiency. Moreover, it was also observed that land size had negative effect on onion yield, which signified the theory of inverse relationship between farm size and productivity in onion production. All these imply that labor market was still imperfect that caused households to rely on family labor. Farmers were more efficient on owned plots than leased (in the form of sharecropping and fixed rent) plots. Tenure insecurity played significant role for farmers to adopt the available technologies and maximize production on irrigated farms. Likewise, land fragmentation has showed positive effect on technical inefficiency, calling for the need to think about land consolidation at least within farms. Hence, it can be concluded that onion production could further be increased by introducing improved water application technologies like drip and sprinkler suitable for small farmers with appropriate policies aimed at creating tenure security, perfecting labor market and consolidating fragmented plots.

Key words: Technical efficiency, stochastic frontier analysis, inefficiency, irrigation, drip, furrow, Kobo, Northeast Ethiopia.

INTRODUCTION

According to World Bank (2007), agriculture has accounted for about 30% of Africa's GDP and 75% of total employment. Over 90% of African agricultural production highly depends on rain-fall. This reveals the fact that erratic rainfall patterns have challenged crop production in these areas and this will be further

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worsened by climate shock which is expected to increase rainfall variability in many African countries.

Technical efficiency measures the relative ability of the farmers to get the maximum possible output at a given level of input or set of inputs. Technically efficient farmers are those that operate on the production frontier which represents maximum output attainable from each input level. All feasible points below the frontier are technically inefficient points. According to Ellis (1988), technical efficiency is the extent to which the maximum possible output is produced from a given set of inputs. On the other hand, a producer is said to be allocatively efficient if production occurs in a set of economic region of the production possibility set.

According to Farrell (1957), there was a growing demand in developing methodologies to be applied for measurement of efficiency. Early methodologies were deterministic frontier models which attribute all deviations from maximum possible output only to inefficiency. However, recent improvement on early methodologies has made it possible to separately account for factors beyond and within the control of decision makers such that only the latter that causes inefficiency. Developments in production frontier have been an attempt to measure productive efficiency. The production frontier shows the range of maximum possible output levels and identifies the extent to which the farmer lies below or on the frontier.

Currently, Ethiopia is the second most populous country in Africa, with a population of more than 85 million and growing at a rate of 2.5% per annum (CSA, 2012). According to World Food Program (2009), economic growth of the country highly depends on the agricultural sector, which accounts for 47% of the GDP and more than 90% of exports, and 83% of the total employment, followed by the service and the manufacturing sectors with a share of 39% and 14% of GDP, respectively. The agriculture sector in Ethiopia is highly dependent on rain-fall and thus more vulnerable to weather shocks. Extreme dependence on traditional technology, rain-fed agriculture, poor supplementary services such as access to extension, credit, marketing, and infrastructure, and poor agricultural policies have been the principal causes of food insecurity in Ethiopia.

Northeast part of Ethiopia is one of the most degraded land, drought, and famine prone areas having high population density. In such areas, the Ethiopian government encourages promotion of effective irrigation based agriculture in the national Plan of Great Transformation Period (MoFED, 2010). Vegetable production is one of the sub sector with huge potential that provide multiple advantages in improving farmers' income benefits and supporting local and national economies.

The purpose of this study is to provide an empirical evidence on the extent and determinants of technical inefficiency in onion production under irrigated agriculture. Specifically, the paper estimates the technical inefficiency of onion production under drip and furrow methods of irrigation and identifies the principal factors that cause efficiency differentials within and between drip and furrow irrigation users.

Description of the study area

This study was carried out in Kobo District. It is located in the North Eastern part of Amhara National Regional State, North Wollo zone, Ethiopia, lying between 11°54'04” and 12°20'56”N latitude and between 39°25'56” and 39°49'04”E longitude (Figure 1). The district has an altitude that ranges from 1400-3100 m above sea level. The District capital town, Kobo, is about 570 km away from Addis Ababa on the way to Mekele (CSA, 2011; WOA, 2010).

According to the North Wollo Zone Agricultural Office (2010), Kobo district shares 43.74% of the total 472927 ha of irrigable land of North Wollo, which is equivalent to 5.5% of the total irrigable land of the region (BoWME, 2005). Kobo district has total human population of 239,504 of which 120,383 (50.26%) are male and 119,121 (49.74%) are female. Out of the total population, 20.15% are urban dwellers. Kobo has a population density of 119.7 people per square kilometre, which is less than the zonal average of 132.3 per km^2. The district has a total area of 2001.57 km^2. With regard to land use pattern of the district, cultivable land comprises the highest (29%) followed by degraded land (26.5%) (CSA, 2011).

According to WOA report (2009), the agro climatic feature of the district is tropical as 7.9, 37.2 and 54.9% are Dega, Weyina dega and Kola respectively. As described by the report of WOA, 65% is plain while the rest (20, 6, 5 and 4%) are mountainous, rugged, gorges and swampy. Kobo is characterized by low and erratic rainfall with mean annual rainfall of 670 mm that ranges from 500 - 850 mm. The temperature varies from a minimum of 19°C to a maximum of 33°C annually. Compared to other districts of the zone, Kobo district has relatively hot climate and it has mean annual temperature of 23.1°C. The landscape of the district is characterized by a broad fertile plain which is separated from low lands of the Afar region by the Noble Mountains, which are over 2000 m high.

METHODOLOGY OF THE STUDY

Sample size and sampling procedure

The data were generated from farm household survey conducted in 2012. A combination of both purposive and two stage stratified random sampling techniques were employed to draw appropriate farm household samples. Kobo district was selected purposively for its long year experience in onion production and consists of both drip

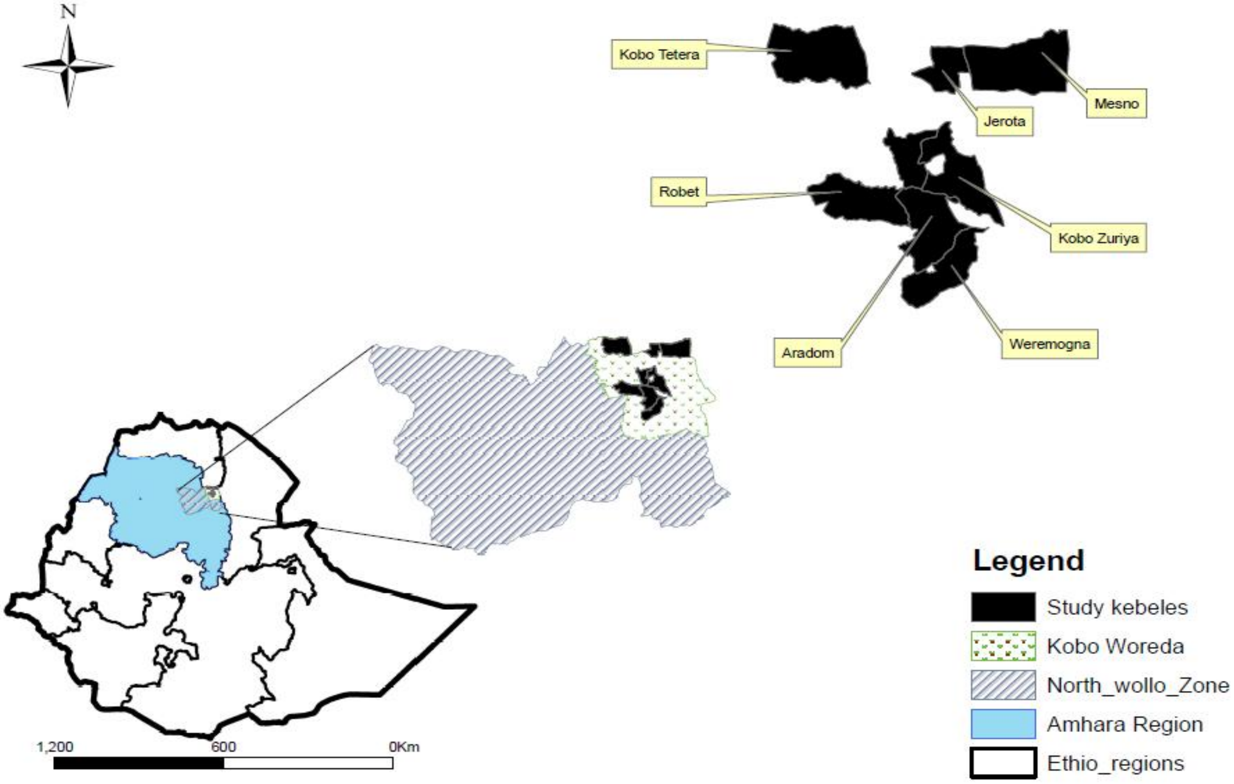

Figure 1. Location of the study area in Amhara National Regional State, Ethiopia.

and furrow irrigation schemes. Since the research focuses basically on onion production, onion producer kebeles were the major target areas for sample selection. In the first stage, out of 25 onion producing kebeles of the district, three namely Aradom, Robit/ Weremogna/ and Jerota/Mesno/ were selected from furrow irrigation users and three namely Kobo zuriya/kebele 3/, Kobo zuriya /kebele 6/ and Kobo zuriya /kebele 7/ from drip irrigation users were selected. In the second stage, a total of 100 households from each group of scheme were selected randomly, using probability proportional to size sampling technique. Finally a total of 200 sample households were selected for interview.

There are several approaches to determine the sample size, out of them Yemane (1967) was used. The total number of household heads in the sampled kebeles of the district is 1,975 (CSA, 2011 and WOA, 2012). Therefore the simplified formula to calculate the sample size used for this particular study was determined at 95% of confidence level and 10% precision. The simplified formula to calculate the sample size is:

$$n = N \Big/ 1 + N(e)^2$$

Where: N = total size of households; n = the size of the sample; e = level of precision.

Data collection and sources

A structured questionnaire was used to guide the data collection from household head through personal interview. The questionnaire was pretested in the field and adjusted accordingly before the interview. Eight enumerators having qualification of diploma and above were trained for three days on how to administer the field interview.

The content of the questionnaire mainly emphasized on household characteristics, land holding, availability and use of inputs, institutional factors, income of the household, allocation and price of each type of farm resource to produce onion, quantity of onion produced, access to agricultural extension services, problems and opportunities in onion production.

Secondary data were also gathered from governmental and non-governmental sources located around the study area so as to back up the primary data. Specifically the price information for basic inputs and output were taken from the Kobo district agriculture office (fertilizer, pesticide and seed) and KGVDP. Moreover, data were extracted from studies conducted and information documented at various levels of Central Statistical Agency, Ministry of Agriculture and Rural Development and Finance and Economic Development Offices in the study area.

Efficiency estimation

There are two approaches to measure technical efficiency: output-oriented and input oriented approaches. In the output-oriented approach, the interest is by how much output could be expanded from a given level of inputs, hence known as output-shortfall. Whereas in the input-oriented approach the concern is by how much inputs could be proportionately reduced to achieve technically efficient level of production, hence, known as input over-use. In this paper, preference was given to the output-oriented approach, in that under traditional agricultural settings the concern is rather not that inputs are over-used but that there is output short-fall (Tewodrose, 2001; Zenebe et al., 2005).

The variation of actual output from the frontier due to inefficiency and random shocks can be captured through stochastic frontier approach. The existence of inefficiency in crop production comes from inefficient use of scarce resources. There exist two main competing methods for analyzing technical efficiency and its principal determinants: the parametric frontier (stochastic frontier approach) and the non-parametric frontier (data envelopment analysis). Non-parametric frontier suffers from the criticism that it takes no account of the possible influence of random shocks like measurement errors and other noises in the data (Coelli, 1995).

The parametric frontier uses econometrics method to estimate the parameters of both stochastic frontier production function and inefficiency effect model. The biggest advantage of stochastic frontier approach is the introduction of stochastic random noises that are beyond the control of the farmers in addition to the inefficiency effects. The disadvantage of this approach is that it imposes explicit restriction on functional forms and distributional assumption for one-sided error term (Battese and Coelli, 1995).

Opposite to the stochastic frontier method, data envelopment analysis is a deterministic frontier, meaning that all deviations from the frontier are attributed to inefficiency only. It is difficult to accept this assumption, given the inherent variability of agricultural production in developing countries due to a lot of exogenous factors like weather shocks, pests, diseases, etc (Coelli and Battese, 1995). Furthermore, because of the low level of education of farmers in developing countries, keeping accurate records is not a common practice. Thus, most available data on production are more likely to be subject to measurement errors. As a result of the above argument, this study employs a stochastic frontier approach introduced by Aigner et al. (1977), and Meeusen and Van den Broeck (1977).

The stochastic frontier method requires a prior specification of the most widely used functional forms like Cobb-Douglas and Translog. Cobb-Douglas is a special form of the translog production function where the coefficients of the squared and interaction terms of input variables of translog frontier are assumed to be zero. Translog frontier is susceptible to multicollinearity even if it is in more flexible form (Thiam et al., 2001). The Cobb-Douglas production function (in spite of its restrictive properties) is preferred because its coefficients directly represent the output elasticity of inputs and easy for interpretation and estimation than translog frontier (Coelli and Battese, 1998; Seymoun et al., 1998). Hence, in this study we preferred to use Cobb-Douglas frontier due to the above reasons.

Cobb-Douglas stochastic frontier production function

The stochastic frontier production function that assumed Cobb-Douglas form is given as:

$$\ell nYi = \beta o + \sum_{j=1}^{n} \beta j \ell nXji + \sum_{K=1}^{m} \beta kDki + Vi - Ui \qquad (1)$$

lnYi denotes natural logarithm of output of ith farm (i=1, 2, ….., n);

β ‘s are the unknown parameters to be estimated;

X_j is a vector of inputs;

D_k is a vector of dummy variables;

Vi is N (0, σ_v^2) distributed random errors;

Ui is the non-negative random variable representing technical inefficiency of production. It is assumed to be distributed independently, which can have either half-normal, exponential or truncated- normal distribution.

δ are the unknown parameter to be estimated;

Z_m is a vector of explanatory variables associated with technical inefficiency of production;

Wi is N (0, σ_u^2) distributed random variable.

The technical efficiency of production for *i*-th farmer is defined by *TEi* = exp(−*Ui*) and the maximum likelihood estimates of parameters in the equation were obtained by following the instruction of Coelli (1996).

Sources of technical inefficiency

The inefficiency model is estimated from the equation:

$$U_i = \delta_o + \sum_{m=1}^{l} \delta_m Z_{mi} + W_i \qquad (2)$$

where Z_i are the variables in the inefficiency component.

Equation 3 shows a joint estimation of a stochastic frontier production function:

$$
\begin{aligned}
&\ell nYIELD = \beta_o + \beta_1 \ell nLAND + \beta_2 \ell nLABOR + \beta_3 \ell nOXENDAY + \beta_4 \ell nUREA + \beta_5 \ell nDAP + \\
&\beta_6 \ell nSEED + \beta_7 \ell nCHEM + Dummy(IRRIMETD) + \delta_o + \delta_1 AGE + \delta_2 FAMILYS + \delta_3 TOTALCUL + \\
&\delta_4 TLU + \delta_5 DISTANCE + \delta_6 EXPERIO + \delta_7 OFFINCOME + \delta_8 INCOME + \delta_9 FRAGMENT + \delta_{10} EDUC + \\
&\delta_{11} OWNERSHIP + \delta_{12} ACCMARKT + \delta_{13} EXTENSER + \delta_{14} ACCSTRAIN + \delta_{15} ACCSCREDIT + \\
&\delta_{16} FIELDVISIT + \delta_{17} RESPONSIB + \delta_{18} FERTILITY + V\}
\end{aligned}
\tag{3}
$$

The first section with β coefficient is the stochastic frontier production function while the second part with δ coefficients estimates determinants of inefficiency. The model generates variance parameters, that is, lambda, $\lambda = \sigma_u / \sigma_v$; variance of the model Sigma (σ), variance of the stochastic model ($\sigma_V^{\;2}$) and variance of the inefficiency model ($\sigma_U^{\;2}$). The variables included in both models are defined as follows:

- YIELD: Physical output is considered as a measure of production so the onion yield measured in tons per hectare was taken as dependent variable in the production function.
- LAND: It was measured in hectare. The land may belong to the farmer, obtained by means of hiring, leasing or through share cropping arrangements. Hence, area of the plot allocated for onion production, in hectare, during 2012 production season was considered for analysis.
- LABOR: This input captures family and hired labour used for different agronomic practices of onion production in the 2012 production season. But the differences in sex and age among labour would be expected. Hence to make a homogeneous group of labour to be added, the individual labour was changed into Man Days (MDs) using the standard developed by Storck et al. (1991). Therefore, the human labour input was expressed in terms of total MDs employed per hectare to perform land preparation, planting, input application, cultivation and harvesting.
- OXEN DAYS (OXDAYS): Given small-scale farmers and less mechanized farming exercise in the study area, oxen day is among major inputs of production. Hence, oxen labour was measured using the total amount of oxen days per hectare allocated for different activities of onion production in 2012 production season.
- UREA AND DAP FERTILIZERS (UREA, DAP): Fertilizer is a key input and its application along with other technologies could have a great potential to increase crop productivity. Urea is applied on the farm land once or using split application, but DAP is usually applied during planting time only. As input variables, the total amount of Urea and DAP used in Kg/ha for the 2012 year onion production were considered in this study.

SEED (SEED): Seed is one of the principal inputs out of which production is not possible. For this study, it refers to the quantity of onion seed (kg/ha) used for onion production during the 2012 production season.
- CHEMICAL (CHEM): Chemical is used as an input particularly in vegetable production due to serious pest and disease attack. As input variable, the total amount of chemicals in Litre/ha was used as protection for onion production during the 2012 season.
- IRRIGATION METHOD (IRRMTD): In irrigated agriculture, the major input is the amount of water applied to the crop. Since it was difficult to measure the volume of water applied, instead irrigation method was used as dummy. Dummy = 1 for drip irrigation and 0 otherwise.

Factors associated with inefficiency as independent variable

After a thorough review of previous studies and the prevailing situation in the study area, socio economic and institutional factors that would affect efficiency were hypothesized as follows:

- AGE OF THE HOUSEHOLD HEAD (AGEHH): The age of the household head is hypothesized to reflect the experience of the farmer.
- EDUCATION LEVEL OF THE HOUSEHOLD HEAD (EDEUCLVL): Farmers are expected to acquire the ability of better management through education and can be used as a proxy variable for managerial ability.
- FAMILY SIZE (FAMSIZE): Family is an important source of labour supply in rural areas. It is expected that households with many family members have better advantage of being able to use labour resources at the right time, particularly during peak cultivation periods.
- TOTAL CULTIVATED LAND (TOTCULTLND): This refers to the size of (own, shared or rented) all land the household managed during 2012 production season.
- LAND FRAGMENTATION (FRAGMENT): This is defined as the total number of plots that the farmer has managed during the 2012 production season. Plots in the area are highly fragmented and scattered over many places that would make difficult to perform farming activities on time and effectively. Increased land fragmentation leads to inefficiency by creating shortage

of family labour, costing time and other resources that should have been available at the same time.

- NUMBER OF LIVESTOCK (LIVESTOCK): This is the total number of livestock in terms of Tropical Livestock Unit (TLU).
- DISTANCE OF HOUSEHOLD'S RESIDENCE (DISTRES): Distance between farmer's residence and onion plot is assumed to have negative impact on efficiency.
- FARM INCOME (TOTFINCOM): This includes all income from on-farm and off-farm activities of the household. It is a continuous variable measured in the amount of income (birr) the household head and/or other members get per year.
- LAND OWNERSHIP (LNDOWNER): This is a dummy variable measured as 1 if the farm for production of onion is on sharecropping basis and 0 otherwise.
- EXPERIENCE IN ONION PRODUCTION (EXPERIO): The number of years of experience is directly related to the farmers' knowhow on onion production.
- OFF-FARM/NON-FARM INCOME (OFFINCOME): Dummy variable has a value of 1 if the farmer is involved in off-farm/non-farm activities, 0 otherwise.
- ACCESS TO CREDIT (ACSCDT): It is a dummy variable which indicates accessibility of credit which is 1 if the farmer can access credit, 0 otherwise.
- EXTENSION SERVICE USE (EXTSERV): Extension service given to farmers was measured as how much farmers implement the advice and techniques given by the extension agent during the production season and was defined using a dummy variable 1 for service user, and 0 for nonuser.
- ACCESS TO MARKET (ACCMKT): It is dummy 1 for those who have access to market, while it is 0 otherwise.
- FIELD VISIT: In the study area, field visit program is adjusted for farmers at their locality and nearby districts in the region. It is dummy 1 for those who have access to field visit, otherwise it is 0.
- ACCESS TO TRAINING (ACCTRAIN): Training is an important tool in building the managerial capacity of the farmer. It is dummy 1 for those who have access to training, otherwise it is 0.
- RESPONSIBILITY (RESPONSI): Responsibility in different social and committee leadership give the farmers opportunity of sharing information on improved production techniques by interacting with other farmers and experts thereby improving efficiency. It is dummy variable taking the value of 1 if the household has different responsibilities in the kebele and 0 otherwise.

RESULTS AND DISCUSSION

Descriptive statistics

Descriptive statistics for the variables used in the model to estimate production and efficiency are described in Table 1. The production function for this study was estimated using eight input variables. To draw some picture about the distribution and level of inputs, the mean and range of input variables are discussed.

Land allocated for onion production

On average farmers produced 6.613 Mt of onion per hectare, which is dependent variable in the production function. The land allocated for onion production, by sampled farmers during the survey period, ranges from 0.05 to 1.25 ha with average of 0.41 ha. The other very important variable, out of which production is impossible, is seed. The amount of seed that the sampled households used was 1.26 Kg, on average. Like other inputs, human and animal labour inputs were also decisive, given a farming system in the study area.

Labor allocation

Sampled households, on average, used 83.15 man equivalent labour and 5.37 oxen days for the production of onion during 2012 production season. In the study area, farmers used both urea and DAP for onion production. Hence, sampled households used 17.32 Kg DAP and 24.56 Kg of urea during the onion production season.

Total of 18 variables were hypothesized to affect efficiency of onion producers, out of which nine of them were dummy variables. Table 2 illustrates summary of these variables. Most of the variables are discussed in the sections of Table 3. Hence, we discussed only some of the variables in the efficiency model. Education level of the households was measured in years of schooling. Sampled households, on average spend $1113 /year for household consumption and other related costs. Almost 49% of farmers reported as they have taken extension service related to onion production. The majority (83%) of the farmers have had their own land; this encouraged them to engage in onion production business in the study area.

Test of hypotheses

Smallholder farmers are characterized by heterogeneity in various aspects of livelihoods like differences in resource endowments, knowledge of farming practices, and other socio-economic factors which could lead to difference in their technical efficiency.

The following hypotheses can be tested using the generalized likelihood ratio test: $LR = -2[L(H0)-L(H1)]$, where L (H0) and L (H1) are the values of log likelihood functions under the null and alterative hypothesis, respectively (Greene, 1980). The null hypothesis is rejected when the calculated chi-square is greater than the critical chi-square with degree of freedom (the number of parameters equal to zero at null hypothesis) at

Table 1. Variables used to estimate the production function analysis.

Variable description	Pooled (200)		Furrow (100)		Drip (100)	
	Mean	SD	Mean	SD	Mean	SD
Yield (Metric ton/ha)	6.613	2.952	5.181	2.057	8.045	2.952
Land (ha)	0.41	0.23	0.33	0.203	0.488	0.23
Seed (Kg/ha)	1.26	0.73	1.055	0.69	1.463	0.73
Human labour (MDs/ha)	83.15	41.31	62.28	23.04	104.02	41.31
Oxen labour (ODs/ha)	5.37	2.43	4.85	1.78	5.89	2.43
Urea (Kg/ha)	17.32	0.73	10.265	9.575	24.39	0.73
DAP (Kg/ha)	24.56	23.7	9.005	11.32	40.12	23.7
Chemicals(lit/ha)	0.172	0.13	0.172	0.13	0.171	0.083
Irrigation frequency (days)	37.1	33.75	4.65	2.88	70	12.43
Irrigation method (Dummy = 1 for drip irrigation and 0 otherwise)	0.5		0.5			

Table 2. Continuous variables used in the efficiency model analysis.

Continuous variable	Pooled		Furrow		Drip	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	46.59	10.78	44.47	9.55	46.59	10.78
Education (years of schooling)	1.625	2.45	1.08	1.68	1.625	2.45
Family size (no)	6.02	1.84	5.92	1.81	6.02	1.84
Total cultivated land (ha)	1.69	0.83	1.51	0.79	1.69	0.83
Fragmentation (Number of plot)	4.12	1.46	3.86	1.26	4.12	1.46
Livestock (TLU)	4.27	2.21	4.42	2.50	4.27	2.21
Distance from residence (Km)	3.54	1.97	3.51	2.54	3.54	1.97
Experience in onion production (years)	5.78	2.64	6.69	3.24	5.78	2.64
Farm income (US $/household)	2273.30	1686.11	1566.16	1016.22	227.3	1686.0

Table 3. Dummy variables used in the efficiency model analysis.

Variable	Pooled		Furrow		Drip	
	Yes in %	No in %	Yes in %	No in %	Yes in %	No in %
Sex (1=male, 0=female)	93.0	17.0	92.0	8.0	94.0	6.0
Extension service use (1=yes, 0=no)	49.0	51.0	42.0	58.0	56.0	44.0
Access to training (1=yes, 0=no)	49.0	51.0	58.0	42.0	42.0	58.0
Access to credit (1=yes, 0=no)	16.5	83.5	16.0	84.0	17.0	83.0
Field visit participation (1=yes, 0=no)	24.0	76.0	22.0	78.0	26.0	74.0
Off-farm income (1=yes, 0=no)	15.5	84.5	16.0	84.0	17.0	83.0
Land ownership (1, if the plot is owned by the farmer, 0, otherwise)	83.0	17.0	89.0	11.0	77.0	23.0
Access to market (1=yes, 0=no)	96.5	3.5	93.0	7.0	100.0	0
Responsibility (household's head role within the community; 1=yes, 0=no)	37.0	83.0	38.0	62.0	36.0	64.0

1%, 5% or 10% level of significance, that is, LR > χ^2C (Kodde and Palm, 1986).

The hypothesis that identifies the appropriate functional form that can adequately represent the data between Cobb-Douglas and Trans-log production function is tested. The hypothesis that shows the appropriateness of

Table 4. Generalized likelihood ratio tests of hypothesis for the parameters of the SPF.

Null hypothesis	DF	LH_o	LH_1	Calculated χ^2 (LR) value	Critical value (χ^2, 0.01)	Decision
Ho: $\gamma = 0$	1	-73.61	-37.59	29.00	6.63	Reject
Ho: $B_{ij} = 0$	45	-37.59	-30.97	13.24	63.69	Accepted
Ho: λ =δ1= δ2=...= δ19=0	19	-73.61	-37.59	72.04	36.19	Reject
Ho: $\sum B_j = 1$		-73.61	-37.59	66.76	6.63	Reject

employing stochastic frontier model over ordinary least square (whether technical inefficiency effect is present in the model or not) is tested. The test is based on the statistical significance of the parameter gamma. This helps to measure the level of farm specific technical efficiency and whether the farmers in the study area are technically efficient or not.

The hypothesis that specifies whether the technical inefficiency effects are jointly significant or not is tested. The hypothesis that specifies whether the stochastic frontier production function is characterized by constant returns to scale or not is also tested.

The first null hypothesis was Ho: $\gamma = 0$, which specifies that the inefficiency effects in the SPF were not stochastic. The null hypothesis was rejected (Table 4). This implies the traditional average production function does not adequately represent the data. Similarly, the second test was the null hypothesis that identifies an appropriate functional form between restrictive Cobb Douglas and the non-restrictive Translog production function which specifies that square and cross terms are equivalent to zero. The test result shows that the null hypothesis accepted implies Cobb Douglas functional form best fit the data set.

The third test of the null hypothesis of all coefficients that explain inefficiency is equal to zero. The result confirms that the null hypothesis was rejected, implying that there is at least one variable that explain the difference in efficiency. The test was what proportion of the existing inefficiency can be represented by the frontier model and the test ratio of gamma in the production function shows that it is rejected at 1% significance level. The last test is to check if the production function exhibits the constant returns to scale.

EMPIRICAL RESULTS

Parameter estimates

The Maximum Likelihood estimates of the parameters of the Stochastic Production Frontier specified in equation 1 were obtained using STATA v10 software program. These results together with the standard OLS estimates of the average production function are presented in Table 5. To include those farmers who did not apply inputs like DAP, UREA and Chemicals in the estimation of the frontier a very small value that approaches to zero was assigned for non-users. Among the total of eight variables considered in the production function, three (land, labour and DAP) have a significant effect in explaining the variation in onion production among farmers. Insignificant variables imply that the variables have no impact in determining the production level of onion in the best practice.

The coefficients of the production function are interpreted as elasticity. Hence, high elasticity of output to irrigation method, labour and oxen suggests that onion production is relatively sensitive to irrigation method, labour and oxen days. As a result, a shift from furrow irrigation to drip irrigation will result in 26% increase in the onion production, 100% increase in labour will result in 14.9% increase in onion production, 100% increase in oxen days will result in 19.8% increase in onion production, similarly 100% increase in urea amount will result in 2% increase in onion production keeping other factors constant. Alternatively, this indicates onion production was positively responsive to irrigation method and labour, followed by oxen days and urea. Land size and amount of seed affect onion production negatively having elasticities of 0.16 and 0.08 respectively (Table 6).

The mean technical efficiency score of drip and furrow irrigation users were 82.59 and 76.80% respectively. But we should take note of the fact that the two groups of farmers were facing two different frontiers. Drip user farmers facing higher frontier than the furrow farmers and were on average more far from their frontier while furrow users were closer to their lower frontier. That is to say the availability of water at any time for drip users had pushed their frontier outwards and made them productive.

Sources of technical inefficiency

The results obtained from the first stage estimations indicate that the average efficiency scores were low and there exists efficiency variations among farmers. The technical efficiency estimates derived from the model

Table 5. Estimates of the average and ML estimates of SPF.

Variable	Coef.	OLS estimate		ML estimate		
		SE	t-value	Coef.	SE	Z-value
Intercept	2.79	0.443	6.32***	3.39	0.305	11.11***
lnLand	-0.124	0.077	-1.61	-0.187	0.043	-4.36***
lnSeed	-0.079	0.072	-1.10	0.011	0.045	0.25
lnLabour	0.174	0.100	1.73*	0.149	0.075	1.98**
lnOxenday	0.220	0.087	2.53**	0.198	0.071	2.79***
lnUrea	0.022	0.006	3.5***	0.019	0.005	3.71***
lnDAP	0.003	0.006	0.43	0.002	0.004	0.41
lnCHEM	0.013	0.008	1.65*	0.012	0.006	2.07**
IRRMTD	0.208	0.075	2.76***	0.260	0.062	4.20***
R^2	0.38			∑β=0.46		
F statistics	14.73***			-		
$\sigma^2 = \sigma_v^2 + \sigma_u^2$				0.275***		
$\lambda = \sigma_u / \sigma_v$	-			8.714***		
γ	-			0.987***		
Log likelihood	-			-72.81		

Note: *, ** and *** are significant at 10%, 5% and 1% significance level, respectively.

Table 6. Production estimates of the OLS and ML estimates for furrow and drip irrigation schemes.

Variable	Furrow users				Drip users			
	OLS estimate		MLE (half normal)		OLS estimate		MLE (half normal)	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Intercept	4.487***	0.789	6.012***	0.459	1.176	1.117	2.06**	0.885
lnLand	-0.143	0.094	-0.188**	0.057	-	-	-	-
lnSeed	-0.058	0.084	-	-	-0.196	0.173	-0.405***	0.132
lnLabour	0.188	0.154	-	-	0.314**	0.143	0.358***	0.091
lnOxenday	0.024	0.152	-0.076	0.105	0.271**	0.114	0.135*	0.08
lnUrea	0.008	0.009	0.019**	0.007	-	-	-	-
lnDAP	0.003	0.009	-0.005	0.007	-0.103	0.123	0.062	0.087
lnChemica	0.017**	0.008	0.006	0.006	-	-	-	-
lnIrrigfreq	-0.139*	0.081	-0.116*	0.061	0.393**	0.161	0.120	0.143
R^2	0.1598		∑β=0.36		0.2396		∑β=0.27	
F statistics	8.52***				5.92***			
$\sigma^2 = \sigma_v^2 + \sigma_u^2$			0.446***				0.3916***	
$\lambda = \sigma_u / \sigma_v$			5.132***			5.54***		
γ			0.8369				0.8471	
LLH			-19.6				-8.013	

Note: *, ** and *** are significant at 10%, 5% and 1% significance level, respectively.

were regressed on socioeconomic and institutional variables that explain variations in efficiency across farm households using Tobit regression model. Hence Table 7 illustrates the socioeconomic and institutional factors that affect efficiency in onion production between drip and furrow irrigation users and within the group.

Table 7. Sources of technical inefficiency.

Variable	Furrow users			Drip users		
	Coef.	SE	Z	Coef.	SE	Z
Intercept	-0.913	2.007	-0.45	3.496	2.271	1.54
Totculand	0.526	0.505	1.04	3.128***	1.182	2.65
Age	0.095**	0.043	2.21	0.064***	0.03	2.11
Plotdist	-0.204*	0.121	-1.68	0.109	0.255	0.43
Educlvl	0.347*	0.201	1.73	0.204	0.174	1.17
Famisize	0.374*	0.201	1.86	-0.317	0.200	-1.58
Fragment	-0.380	0.242	-1.57	-1.019***	0.457	-2.23
Accstrain	-0.439	0.688	-0.64	-1.405**	0.696	-2.02
Accsmakt	-2.221**	0.926	-2.40	--	--	--
Extenserv	-1.123*	0.675	-1.66	2.293	1.74	1.32
Ownership	--	--	--	-1.665*	0.892	-1.87
Experionp	-0.086	0.099	-0.87	-0.513	0.364	-1.41
Farminco	-0.0002***	0.00006	-3.42	-0.0001***	0.00003	-3.92
Fldvisit	-0.502	0.863	-0.58	-4.30*	2.572	-1.67
Responsib	1.731**	0.692	0.78	0.158	0.773	0.20
LLH	-19.60			-8.013		
Mean TE	0.768	0.203		0.826	0.158	

Note: *, ** and *** are significant at 10%, 5% and 1% significance level, respectively.

The result indicated that the sources of technical inefficiency under furrow and drip irrigation are different. While household head age and total farm income induce technical inefficiency in both irrigation schemes, plot distance, education, farm size, access to market, extension service and household head role within the community induce inefficiency only in furrow irrigation. Inefficiency in drip irrigation is significantly related to total cultivated land size, extent of land fragmentation, access to training, field visit and whether the plot is owned by the farmer or not. This result clearly indicated that technical inefficiency is explained by land related factors such as ownership of land, total farm size and land fragmentation. Both total cultivated and owned land sizes have statistically significant negative effect on production efficiency.

Total cultivated land was found to have significant and negative impact on TE, the result is in conformity with the results of Assefa (2011), Wondimu (2010) and Getachew (1995), but opposes the research findings of Steven and Edward (2004). In general, the result is consistent with the theory of inverse relationship between farm size and productivity. Given the requirement of close monitoring and labour intensive production, since it is produced for market purpose, the negative effect of total farm size on TE could be because of the managerial and input competition. In this study, more specifically, the explanation to the inverse relationship between farm size and technical efficiency is mainly related to the labour market imperfection. As long as hired labour is less efficient than family labour, an increase in farm size leads to inefficacy because family labour can handle only part of the farm operations in a bigger farm size. This is typically true to onion production, which requires a lot of labour for production as well as marketing. Farmers with bigger farm size may adopt the available technology, but its actual implementation depends on how efficient is the farm labour and they should also give due attention towards improving the existing level of labour inefficiency of farmers. More importantly the working culture and perception on improved technologies in that area should be improved. However, not all family labours are equally efficient. Our estimate showed that experience in onion production, age and education are important. The coefficient for onion production experience was negative and significant, indicating that more experienced farmers tend to be more efficient. This may be due to good managerial skills, which they have learnt over time. We also observed that aged people are less efficient than young people who are enlightened to adopt new technologies better than older ones.

The effect of land ownership was found negative and significant for drip irrigation users. Drip irrigation requires high investment that will be made if and only if the farmers are secure to use the land for longer periods. Thus, if the plot is owned by the farmers, they opt for adopting the best technology to maximize profitability. However, if the land is leased in the form of sharecropping or fiend rent contract, this will not be the case. The result confirms such hypotheses. Onion plots owned by the farmer are more efficiently used than leased in plots. Tenure security has been always an issue in farm investments. This is evidence on irrigated agriculture that is essential in dry land areas.

Field visit was found to have significant and positive impact on TE, which is as expected since field visit improves the technical knowhow and skill of the farmers through practical experience sharing on other areas of the same groups of producers. Access to training service was also found to be significant and has positive impact on TE. Farmer's access to training enhances their crop management skill and timely utilization of inputs thereby improving productivity via efficiency. The findings are consistent with earlier results by Assefa (2011) and Idiong (2007). Generally, sustained growth in farm productivity may also be dependent on improvements in several aspects of human capital including education, health and nutrition attainment in rural areas.

CONCLUSION AND POLICY IMPLICATIONS

The average technical efficiency of farmers who use drip irrigation scheme is higher than that of furrow scheme users; and also the average yield obtained by sample farmers in drip irrigation scheme users was higher than that of furrow irrigation scheme users mainly because of the fact that they apply the recommended level of inputs and availability of water specifically during critical water requirement period of the crop. Given the limited resources in the study areas, efforts to strengthen the efficiency of smallholder farmers who are the largest segment in agricultural production are indispensable. The existence of inefficiency in both irrigation scheme users shows there is a room to increase the yield of onion by improving the use of existing technologies by all farmers without introducing new technology.

Extension agents, as they are employees deployed to work very close to farmers, a lot is expected from them. Consequently, the results of the study revealed that the utilization of extension services has positive influence on technical efficiency of the sample farmers. Therefore extension services have to keep on aiming to provide information and practical farming knowledge for all farmers particularly those involved in irrigation to improve resource utilization and reduce cost of production in irrigated agriculture.

In the study area, field visit promotes technical efficiency of irrigated onion production. This indicates that the existing training and field visit experience sharing services should be continued and promoted in improving the technical efficiency and thereby the performance of farmers. Therefore, it is recommended that government should have a prime responsibility to improve the performance of farmers training center much more in these areas and others so that farmers can use the available inputs more efficiently under the existing technology. More importantly, practical training should be planned to be comprehensive in considering issues like efficient resource use (land, labour, fertilizer and seed), cost reduction, profit maximization objectives so that farmers could be benefited from accelerated increase in income from onion production.

This study has revealed that small scale onion producer farmers are not fully technically efficient and therefore there is allowance of efficiency improvement by addressing some important policy variables that negatively and positively influenced farmers' level of technical efficiency in the study area. The positive elasticity of urea in the case of furrow irrigation scheme users and labor and oxen days in the case of drip irrigation users shows the increased use of this input which can increase the yield of onion; therefore timely availability of this input is crucial.

The result also revealed that land related factors such as land size, land ownership, and land fragmentation explain much of the technical inefficiencies in addition to other socio-economic characteristics of farm households. Total land size is inversely related to the technical efficiency. We also observed that land size has negative effect on onion yield, which signifies the theory of inverse relationship between farm size and productivity in onion production.

All these imply that labor market is still imperfect in that it causes households to rely on family labor. Farmers are more efficient on owned plots than leased in (in the form of sharecropping and fixed rent) plots. Tenure insecurity plays significant role for farmers to adopt the available technologies and maximize production on irrigated farms. Likewise, land fragmentation has showed positive effect on technical inefficiency, calling for the need to think about land consolidation at least within farms. Hence, it can be concluded that onion production can further be increased by introducing improved water application technologies like drip and sprinkler suitable for small farmers with appropriate policies aimed at creating tenure security, perfecting labor market and consolidating fragmented plots.

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