Estimating Profit and Technical Efficiency of Small-scale Irrigation Shallot Farming: A Case Study of Godino Peasant Association in Ada *Woreda*, Oromiya Region, Ethiopia

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Abstract

Limited information exists on the economics of horticultural production in Ethiopia. For instance, while the yield of shallot is fairly known, its production costs and benefits are grossly unknown. The objective of this study was, therefore, to estimate the profit and technical efficiency of small-scale irrigation farming by monitoring the costs incurred. Based on farm-level data from 106 small-scale irrigation producers, the farm level profit and output-oriented technical efficiency indices were determined using the SPSS computer package and stochastic production function, respectively. The average cost to produce one kilogram of shallot was estimated at Birr 0.72 whereas the average farm gate price was estimated at Birr 1.87. This indicated that producing shallot under small-scale irrigation farming is a financially viable venture, and it significantly contributed to household cash income and food security. The profit levels at the the three studied areas ranged from24-145%. The stochastic frontier results revealed mean technical efficiency of 0.77 for all the farms. This means that average levels of farms were below the frontier by 23%, which otherwise means that the total output of shallot could be increased by up to 23% above the actual output levels attained in the study area during the survey year. The most limiting factors for small-scale irrigation farming were the demand of the irrigation husbandry for strenuous efforts of the farmers (95%), lack of fertilizer (91%), input-costs (70%), lack of credits (45%) and shortage of water in May (30%).

***Key Words**:* Shallot, small-scale irrigation, stochastic frontier, technical efficiency

Introduction

Increased irrigation efficiency implies a change in technology through adoption of improved varieties, drip irrigation, canal lining, and improved management practices (irrigation scheduling and crop water requirements) or both (Skaggs and Samani, 2005). Technological change in irrigation practices has been dramatic over the past century. The adoption of new technologies in small-scale irrigation should drive down real commodity prices, increase productivity, reduce production costs and change agricultural structure. What Backeberg and Sanewe (2006) called the "technological treadmill" is credited with mass migration of people out of agricultural ventures, reduced number of farms, increased average farm size, reduced rural population and the current trend of dual-farm structure. However, potential responses to production costs for improving irrigation efficiency have not been explored in the Godino area of East Shewa in Ethiopia because irrigation users considered it as a traditional business-like objective or lifestyle activity. Most of the small-scale irrigation operators throughout the country are not strongly motivated by business or commercial objectives (e.g. increased revenues, profit and reduced costs) (Abate and Eshetu, 2004). The large, commercial irrigation farms in the country are motivated by the profit they earned than those of smaller, lifestyle irrigation farms. In fact, all farms, regardless of their size, are facing fertilizer shortage and long-term competition for existing dam water supplies due to long drought.

In line with the extensive assessments of the impact of irrigation technology on small-scale irrigation practices (Hallam, 1993), preceding attempts towards identifying the factors influencing the likelihood and extent of technology adoption elucidated biological age, period of irrigation farming experience, educational level, on-farm employment opportunity, level of involvement in farm organizations, wealth status, and risk expectation and mitigation orientations amongst the major individual farmers' characteristics usually associated with technology adoption and small-scale irrigation efficiency (Rogers, 1983). Furthermore, field studies have emphasized that successful small-scale irrigation farming requires low-cost focused research and development interventions, ensuring irrigation water development at releasable charges, development of market and market information services, and adequate rural power supply and funding provisions (Kulecho and Weatherhead, 2006).

For resource-poor farmers, cost is an economic indication to abandon or continue using small-scale irrigation farming. For some farmers of the developing nations, profit is considered to be far more important than cost to abandon or continue small-scale farming because it is an end to justify the means.

The present study was, therefore, undertaken with the objective of examining the production cost of small-scale irrigation shallot farming so as to determine its profitability and efficiency under situations of lack of commercially sustainable markets.

Methodology

Description of the study area

Godino, the small town within the study area (Fig. 1), has a successful community in the Oromiya Region based entirely on the forward and backward linkage of small-scale irrigation**.** Farmers in the study area have been producing horticultural crops under irrigation fairly well for many years using traditional production system. But their livelihoods are affected by lack of access to free market and inability to sell their produces at competitive prices outside their environment, small irrigated land size, low household income, large family size and low level of education. This study covered three villages of small-scale irrigation farmers in Godino Peasant Association. The three villages of small-scale irrigation farmers included in the study were the following (Fig. 1).

1) ***Gohaworko village***: Farmers in this village are more business-minded and are aware of technology and market than the other two villages. Farmers are cash-oriented and concentrated mainly on the production of shallot, sugar cane, and tomato under irrigation. Most of these farmers practice mixed cropping system in which cabbage is grown between shallot, potato and sugar cane.
2) ***Godino village*:** Farmers in this village are less focused on agribusiness and produce food crops for home consumption and selling where surpluses are available. They diversify production and grow crops such as shallot, chickpea, lentil, and tomatoes under irrigation.
3) ***Keteba village*:** This village is situated to the north of Godino town. Farmers in this village are less focused on marketable horticultural crops because they have poor access to market. They grow shallot, chickpea, and lentil under irrigation, mostly for food security purpose (self consumption).

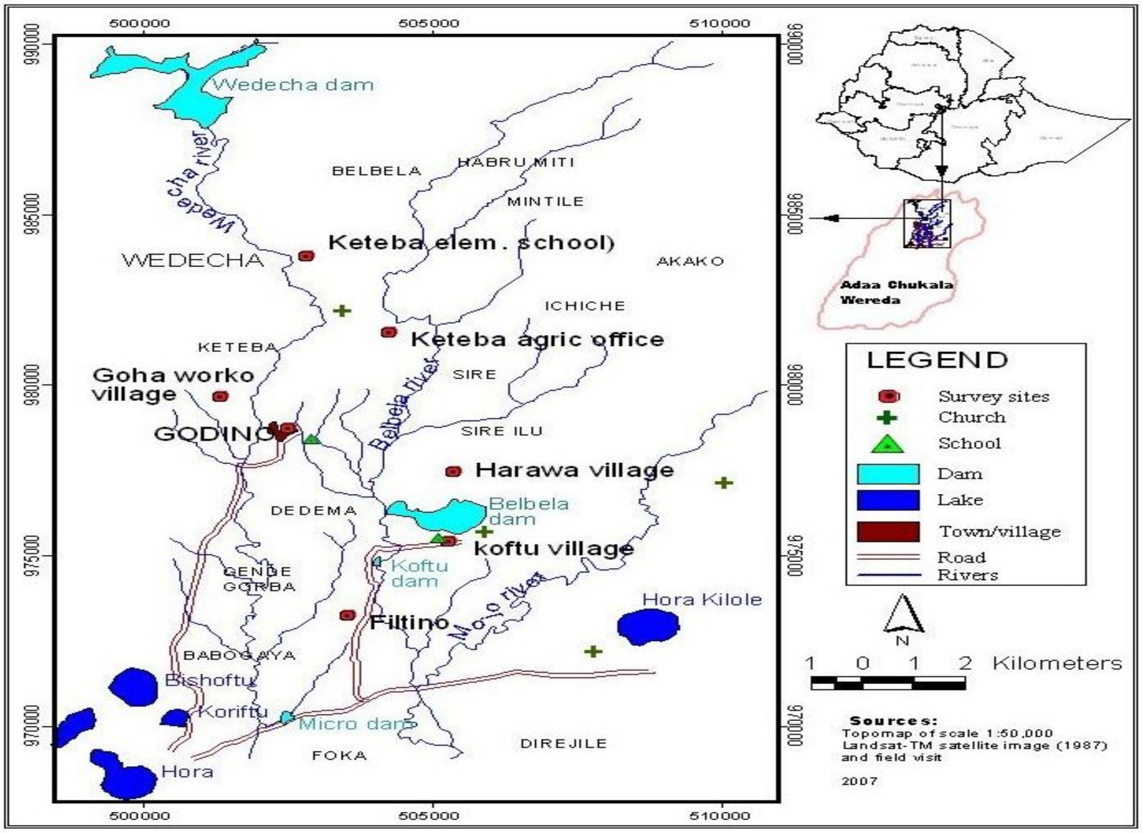

Fig. 1. Map of irrigation sites comprising the case study villages

Survey design and sampling

Farmers' fields at the three villages were monitored on a weekly basis over the 2007/08 production year. The monitored farmers selected from the three villages were located at range of 10-15 km from each other. The predominant crops selected for the study were shallot and potato, but this paper concerned the results with shallot only.

The study was based on a farm-level data of 106 randomly selected farm households who had access to irrigable land.

Farmers in the study area usually practice both early (October) and late (December) planting. The data collection and monitoring during the growing season were done following the standard procedures and recoding formats for farm operations. The input parameters recorded could be categorized into labor, planting materials, fertilizer, chemical and oxen-hours. Field records and observations were made on land preparation for three to four times, planting for one to two times, duration of irrigation at each irrigation, weeding/cultivation at each weeding, chemical application at each application, and harvesting and crop yield one to two times at and after harvesting, respectively.

Data analysis

Descriptive statistics on costs and returns were generated using the SPSS computer package whereas the technical efficiency indices of resource use were determined by fitting stochastic production function (Coelli and Battese, 1996) to the survey data collected from 106 shallot producers.

By definition, the stochastic frontier production function is:

$\ln(Y_i) = \beta_0 + \beta_1 \ln(Area_i) + \beta_2 \ln(Seed_i) + \beta_3 \ln(Labor_i) + \beta_4 \ln(Traction_i) + \beta_5 \ln(P_2O_{5i}) + \beta_6 \ln(N_{2i}) + \beta_7 \ln(Pesticide_i) + Vi - Ui$ -..............(Equation1)

Where:

the subscript i indicates the i-th farmer in the sample (i =1, 2,……, N); ln represents the natural logarithm (i.e., logarithm to base e);

Y_i is the yield of shallot (quintal*/ha);

Area, seed, labor, traction, fertilizer (P_2O_5 and N) and pesticide refer to shallot area and inputs used;

The βs are unknown parameters to be estimated;

The V_is are assumed to be independent and identically distributed random errors having a normal (0, σ_v^2) distribution; and

The U_is are non-negative random variables, called technical inefficiency effects, which are assumed to be independently distributed such that U_i is defined as α by the truncation (at zero) of the normal distribution with mean, μ_i, and variance, σ^2,

where μ_i is defined by

$\mu_i = \alpha_0 + \alpha_1 (Age_i) + \alpha_2 (Farming\ experience_i) + \alpha_3(Education_i) + \alpha_4 (Family\ size_i) + \alpha_5(Land\ ownership_i)$.. (Equation 2)

Where α-coefficients are unknown parameters to be estimated, together with the variance parameters, which are expressed in terms of age, farming experience, education, land ownership, and family size and income.

The stochastic frontier model for shallot producers is defined by Equations (1) and (2). The production function, defined by equation (1) specifies that the three villages have obtained different mean levels of shallot output.

The model for the technical effects, defined by equation (2), implies that the technical inefficiency effects in the stochastic frontier equation (1) are a function of age, farming experience, education, family size and land ownership. More years of formal education and farming experience are expected to result in smaller values of the technical inefficiency effects, whereas the older farmers, family size and rent-in land for irrigation are expected to have greater inefficiencies.

The maximum likelihood estimates for the parameters of the stochastic frontier were obtained by using the program, the FRONTIER Version 4.1 (Coelli, 1996). Estimates of the variance parameters are as follows:

$\sigma_s^2 = \sigma_v^2 + \sigma^2$ ---------(Equation 3)

$\gamma = \sigma^2 / \sigma_s^2$

The γ-parameters indicated above have a value between zero and one. The discrepancy parameter γ is an indicator of the relative variability of the two error components (σ_v^2 and σ_s^2). If γ approaches to zero, it implies that the random effect dominates the variation between the frontier output level and the actually obtained output level. Conversely, as γ approaches to one, it can be assumed that the variations in outputs are determined by technical inefficiency.

Results and Discussion

Determination of profit

The average cost of inputs and profit obtained from shallot production are summarized on Table 1. The average irrigated area per farmer or per household 0.21 ha, indicating that shallot is grown on smallholdings. The small farm size could either be due to labor-intensive nature of the cultural practice involved or because the producers could not afford to purchase and work on more land. The major cultural practices considered in shallot production were land preparation, plowing, irrigating the crop, planting, weeding and harvesting. All these practices require substantial amount of labor, averaging 265.71 man-days/ha.

Yields were estimated at 19.06, 12.54 and 15.73 t/ha for Gohaworko, Godino and Keteba, respectively. Likewise, the total costs were estimated at 10,676.38 Birr/ha, 9,401.07 Birr/ha and 13,981.68 Birr/ha for Gohaworko, Godino and Keteba, respectively. Consequently, the net profits were estimated at 24,488.23 Birr/ha for Gohaworko, 13,946.26 Birr/ha for Godino and 17,023.72 Birr for Keteba. The majority (94%) of the shallot producers obtained substantial profit of 16908.07 Birr/ha from shallot production. The results from efficiency models showed that the margin could be larger if irrigated land size was to increase.

Production cost structure

Production cost structure explains what and which input makes up the largest proportion in the cost.

The basic presumption behind the need for knowing the cost structures and proportions in any commodity production are for comparison and decision making purposes. Thus, for the present study, the production cost structure proportions computed based on the estimates of the major production cost items revealed that about 39% and 36% of the total cost went to seed and labor, respectively (Table 2). In this context, small-scale irrigation farming appeared to have been absorbing ample human resource that could have been idle during the off-season. However, it is arguable that small-scale farmers should use labor and seed more effectively to increase their profit. This stated otherwise means that cost minimization of seed and labor can be a more appropriate behavioral change than maximization of profit which is a gradual process.

Table 1. Average costs (Birr/plot) of inputs for shallot production in the three selected villages surveyed during the 2007/08 irrigation season

Descriptive information	Gohaworko (n = 45)*	Godino (n = 31)	Keteba (n = 30)	Total (n = 106)
Mean irrigated land (m^2)	1451.00	3251.00	1859.00	2093.00
Mean yield (t//plot)	2.79	3.82	2.74	3.08
Gross income (Birr)	5100.89	6811.13	5600.28	5742.39
Labor cost (Birr)	590.91	1058.91	837.82	797.66
Traction cost (Birr)	150.81	353.47	329.61	260.68
Seed/seed material cost (Birr)	495.56	1148.28	1158.33	874.03
Fertilizer (DAP & urea) cost (Birr)	192.04	292.26	215.33	227.94
Pesticide cost (Birr)	5.96	23.45	3.56	11.30
Other costs (Birr)	33.93	59.72	15.55	38.36
Total production cost (Birr)	1463.87	2936.78	2555.32	2203.53
Production cost (Birr/kg)	0.53	0.77	0.93	0.72
Profit per plot (Birr)	3637.02	3874.35	3044.95	3538.86
Profit per m^2 (Birr)	2.45	1.40	1.70	1.93
Profitability (%)	245.13	150.68	124.11	183.26

**n = number of sample farmers*

Table 2. Proportion (%) of production costs in the three study village surveyed during the 2007/08 irrigation seasons

Descriptive information	Gohaworko (n = 45)	Godino (n = 31)	Keteba (n = 30)	Total (n = 106)
Labor cost (%)	39.04	36.60	32.70	36.12
Traction cost (%)	10.15	12.24	12.87	11.55
Seed/seed material cost (%)	33.95	37.25	44.38	38.52
Fertilizer (DAP & urea) cost (%)	14.11	11.06	9.25	11.84
Pesticide cost (%)	0.36	0.67	0.11	0.41
Other costs (%)	2.44	2.20	0.72	1.76
Total (%)	100.00	100.00	100.00	100.00

**n = number of sample farmers*

Efficiency of resource use

In addition to the information generated on input use, unit price and output levels, some additional information was obtained on socio-economic characteristics of the producers. To this end, a production function was employed to estimate the resource use among the producers. Descriptive household statistics for the input factors and relevant socio-economic variables considered in this study are presented on Table 3.

Table 3. Means for household socio-economics descriptive statistics of sampled shallot farmers surveyed in the three villages during the 2007/08 irrigation season

Description	Unit	Gohaworko (n = 45)	Godino (n = 31)	Keteba (n = 30)	Overall mean (n =106)
Irrigated area	m^2	1451.00	3251.00	1859.00	2093.00
Yield	Kg	2784.44	3827.42	2738.83	3076.56
Seed	Kg	390.31	842.29	799.33	638.25
Labor	Man-day	39.40	70.59	55.86	53.18
Traction	Oxen-day	3.35	7.86	7.33	5.80
P_2O_5	Kg	20.24	25.23	24.78	22.98
Nitrogen (N)	Kg	10.58	22.78	16.60	15.85
Pesticide	Liter	0.38	0.32	0.22	0.31
Other costs	Birr	33.93	59.72	15.55	38.37
Age	Year	32.62	35.97	37.30	34.93
Education	Year	6.02	4.87	2.93	4.81
Experience	Year	10.89	12.87	8.83	10.86
Family size	Number	3.38	5.84	5.10	4.59
Land tenure	Dummy	1= if irrigated land owned and 0= otherwise			

**n = number of sample farmers*

Maximum likelihood estimation

One can use either a farm group or a merged analysis to determine the maximum likelihood estimation. The question is which approach will be best to estimate the parameters. The merged farm analysis approach is more appropriate when the farms considered are located in the same region, have the same production sets and share the same support structures. When farms do not have the same production function, the analysis for the three groups should be done separately (Assefa and Heidhues, 1996). The maximum likelihood results of the estimation of the parameters of the stochastic frontier production function are presented on Table 4. The values of the likelihood ratio sigma-square (σ^2) and gamma (γ) are statistically significant. This indicates that the frontier model is an adequate representation for the farms considered in the study.

Table 4. Maximum-likelihood estimates for parameters of the stochastic frontier shallot production and inefficiency models for farm households, 2007/2008 irrigation season

Variables	Parameters	Coefficients	Standard errors
Stochastic Frontier			
Constant	β_0	7.8515**	0..0205
ℓn (shallot area)	β_1	0.2561***	0.0020
ℓn (seed)	β_2	0.1463***	0.0744
ℓn (labor)	β_3	- 0.0245	0.0692
ℓn (traction)	β_4	0.0522*	0.0494
ℓn (phosphorous)	β_5	0.1206***	0.0432
ℓn (nitrogen)	β_6	0.1035*	0.0917
ℓn (pesticide)	β_7	- 0.0136	0.0165
Returns to scale		**0.6406**	
Inefficiency Model			
Constant	α_0	0.5494***	0.0920
Age	α_1	- 0.0113**	0.0072
Farming experience	α_2	- 0.0184***	0.0051
Education	α_3	- 0.0028***	0.0006
Family size	α_4	0.0394	0.0582
Land ownership	α_5	0.0581	0.0495
Variance parameters	σ^2	0.07133***	0.0145
	γ	0.9505***	0.0390
Log-likelihood function		85.82	
Average technical efficiency		0.7731	

****, ** and * indicate statistical significant differences from zero at 1%, 5% and 10% level*

As expected, the estimated coefficients of all the input variables in the production function have positive signs, except for the labor and pesticide inputs. An increase in irrigated area by 10%, *ceteris paribus,* will increase shallot yield by about 2.56%. A similar increase in seed is expected to result in 1.46% increase in shallot yield. Application of phosphorus (P_2O_5) and nitrogen (N_2) also led to significant increases in yield. The results indicate that land area and seed contributed the most to growth in shallot yield. Labor and pesticide inputs have negative signs, though the results were not statistically significant. This indicates that the sample farmers used too much of these inputs.

Causes of inefficiency in small-scale irrigation farming were determined with the stochastic frontier model in single-stage maximum likelihood estimation. Of the estimated coefficients of the inefficiency variables, experiences in irrigation farming, education, age of the household head were statistically significant (Table 4). This means that irrigation farming experience, education and age of the household head reduce inefficiency whereas family size and land ownership increase inefficiency of small-scale irrigation farming. Farming experience and education may be advantageous not only to increase efficiency, but also in helping farmers learn to adjust resource use to changing conditions so as to maintain high levels of efficiency (Norton and Alwang, 1993).

The sum of the output elasticities is calculated to be more than one (0.64), which indicates that farms are operating in the rational frontier of production (decreasing returns to scale) (Table 4).

Frequency distribution of technical efficiency

The frequency distribution of the predicted technical efficiency and the summary statistics for shallot producers under small scale irrigation are presented on Table 5. The predicted technical efficiencies for farms in Gohaworko vary between 0.40 and 0.97 with a mean of 0.83. Farms in Godino and Keteba, on the other hand, are operating at mean technical efficiency of 0.76 (range 0.35-0.98) and 0.70 (range 0.41-0.93), respectively.

Comparatively, about 64.4% of the farms in Gohaworko, 38.7% of the farms in Godino and 33.3% of farms in Keteba are clustered between technical efficiency values of 0.81 and 0.95. This implies that the majority of farms in Gohaworko achieved higher technical efficiency than farms in Godino and Keteba. Four farms (8.9%) from Gohaworko, two farms (6.5%) from Godino and one farm (3.3%) from Keteba operated at frontier level of 0.95-1.00. On the basis of the standard deviation and coefficient of variation of the data, it can be concluded that the technical efficiency of farms in Gohaworko is more stable than that of farms in Godino and Keteba. The overall t-value indicated statistically significant ($P \leq 0.01$) difference in the efficiency indexamong the three villages.

Table 5. Frequency distribution (%) of technical efficiency in the stochastic shallot production frontiers of the three villages surveyed during the 2007/08 irrigation season

Efficiency intervals	Gohaworko (n = 45)	Godino (n = 31)	Keteba (n = 30)	Overall mean (n =106)
	%	%	%	%
0.35-0.50	4.4	3.2	16.7	7.5
0.51-0.65	8.9	16.1	23.3	15.1
0.66-0.80	13.3	35.5	23.3	22.6
0.81-0.95	64.4	38.7	33.3	48.1
>0.95	8.9	6.5	3.3	6.6
Mean	0.8326	0.7614	0.6959	0.7731
Minimum	0.40	0.35	0.41	0.35
Maximum	0.97	0.98	0.93	0.98
Std. Dev.	0.136	0.145	0.157	0.154
CV (%)	16.33	19.04	22.56	19.92
T-value		8.16***		

*** Indicates significant efficiency index difference among villages at $P \leq 0.001$

Conclusions

Considerable variations in the gross incomes and costs were observed among the three surveyed villages. For instance, yield of shallot varied from 12.5-19.0 t/ha among the farmers' fields. In spite of the strenuous efforts made by farmers and the short-term high cost, the study results confirmed that small-scale irrigation farming is not only a financially viable venture, but it has also significantly contributed to household cash income and food security.

In the production cost structure, the highest proportion went to cost of labor (39%) and seed material (36%).The average cost to produce one kilogram of shallot was estimated at Birr 0.72 whereas the average farm gate price farmers received was Birr 1.87. In spite of this, consumers' prices are paradoxically 2-3 times more than that of the farm gate prices. However, the huge gap between farm gate and consumers' prices need further follow-up study of the entire market chain. The mean technical efficiency as revealed from stochastic frontier analysis was 0.77, indicating that average levels of farms were 23% below the frontier. This also means that the total output of shallot could be increased by up to 23% above the actual output levels attained in the study during the survey year.

From the estimated coefficients of the technical efficiency variables, land/farm area and seed material accounted for the most part of the shallot yield growth whereas experiences in irrigation farming, level of education and age of the household heads constituted the most important variables to reduce inefficiency.
The most limiting factors identified for small-scale irrigation farming were the demand for framers' strenuous efforts posed by the irrigation farming practice *per se* (95%), lack of fertilizer (91%), input-cost (70%), lack of credits (45%) and shortage of water during the month of May (30%).

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