A Comparative Analysis of the Technical Efficiency of Irrigated and Rainfed Agriculture:

A Case of Awash and Rift Valleys of Ethiopia

Dawit Kelemework

Department of Economics, Haramaya University

dawitkelemework@yahoo.com

Abstract

Ethiopia's economy is heavily dependent on the agricultural sector, which contributes 45% of the GDP, providing livelihood for 85% of the population and accounting for 60% of the foreign exchange earning. Ethiopia, one of the poorest countries in Sub-Saharan Africa, has been repeatedly hit by drought resulting in famine and the loss of life of thousands of its rural citizens. The country's agriculture mainly depends on rain fed peasant farming which accounts for 96% of the food produced in the country. On the other hand, it is estimated that the major river basins of the country can irrigate about 3.5 million-hectare of land and at present only about 161,010 ha or 4.6% is irrigated around the major river basins. Though the expansion and better utilization of this irrigation potential is unattested, the production efficiency of the existing irrigation systems also needs attention. This paper compares the technical efficiency of rainfed and irrigated agricultural production in Ethiopia. Using the stochastic production frontier approach, the study concludes that the existing irrigation systems are not that efficient and there is a need to make them operate near their production frontier. The production frontiers of both irrigated and rainfed agriculture is estimated along with the technical efficiency of each farmer in both groups and the two groups are compared in relation to their respective frontiers. The marginal and average productivities of the important factors of production is also calculated and compared.

1. Introduction

Ethiopia has a total land area of about 113,000,000 hectares (Annual Report in the Ethiopian Economy, 1999). The economy is heavily dependent on the agricultural sector, which contributes 45 percent to GDP, 60 percent of the foreign exchange earnings and provides livelihood to 85 percent of the population (EEPRI, 2005). Of the arable land, only 40 percent is currently cultivated (Awulachew et al, 2005). As a result of the importance of agriculture in Ethiopia's economy, the government has embarked on an agriculture centered rural development program which is meant to spearhead the country's economic development program (Government of the Federal Republic of Ethiopia, 2003). Irrigation development is viewed as an integral part of this economic development program as promulgated by the Ethiopian Water Sector Strategy (Federal Democratic Republic of Ethiopia, 2001).

It is estimated that the major river basins of the country can irrigate about 3.5 million-hectare of land. At present only about 161,010 ha or under five percent is irrigated (Annual Report on the Ethiopian Economy). The private sector accounts for 6,000 ha of the developed irrigated area (Amare, 2000). Unpredictable rainfall coupled with a high rate of population growth, makes Ethiopia unable to feed its people. Even under favorable growth scenarios of rain fed agriculture, the country still faces a deficit of food crops.

The policies for economic development are formulated in an environment which can be referred to as the "Ethiopian Paradox". The Ethiopian Water Resources Management Policy (1999) states that Ethiopia is endowed with relatively higher amounts of rainfall in the region and has a surface runoff of about 122 billion cubic meters of water, excluding ground water. The same document also states that "…a number of studies made in the field confirm that if the country's water resources are developed to cater for irrigation, it would be possible to attain agricultural surplus enough both for domestic consumption as well as for external markets." pp VIII. However, even given this estimated potential, Ethiopia continues to be a recipient of food aid.

Irrigation development is therefore perceived as one of the strategies for alleviating the paradox. The government of Ethiopia has an irrigation development strategy which aims to develop over 470,000 ha of irrigation by 2016. Fifty two percent of this development will be large and medium scale schemes while the remaining 48 percent will be small scale schemes16 (Federal Democratic Republic of Ethiopia, Water Sector Development Programme 2002-2016). Small scale irrigation development is therefore envisaged to play a critical role in the government's strategy for addressing the food security situation in Ethipoia and solving the paradox. However, the estimated area under small scale irrigation is owever, only 68,210 hectares in 1996/97 (CSA, 1998), only 30 percent of what the government plans to develop by 2016, showing that this irrigation sub sector still has great potential for contributing to the Ethiopian's government development objectives.

During the former Derg17 regime, many small scale irrigation schemes were collectivized. They were generally poorly operated, managed and maintained and currently most, if not all, need for rehabilitation (CRS, 1999). Many small-scale irrigation infrastructures, especially traditional diversion weirs, which tend to be washed away by flash floods, need annual upkeep. Siltation and damage within the canal system from flooding are also major concerns for small scale irrigation (ibid). The degradation of upper catchments and watersheds in many areas does not help the situation (ibid).

Because of the ambitious government plans to expand small scale irrigation in Ethiopia, it is important to study, among other performance parameters, the production efficiency of small scale irrigation schemes . Many believe that the existing irrigation schemes are not operating efficiently, and that much has to be done to improve their efficiency. For example, CRS (1999) has identified that the existing small scale irrigation schemes exhibited inefficient use of water, leakage from unlined canals and faulty usage of irrigation water. This study estimates the technical efficiency of small scale irrigation in Ethiopia.

2. Objectives

The objectives of the study are to:

estimate and compare the technical efficiency of dryland and small scale irrigation farmers.

compare the technical efficiency of different small scale irrigation schemes and

[16] According to Awulachew et al (1999) irrigation projects in Ethiopia are identified as large-scale irrigation if the size of command area is greater than 3,000 ha, medium scale if it falls in the range of 200 to 3,000 ha, and small scale if it is covering less than 200ha.

[17] Desalegn and Miheret, 2004 characterized the Derg regime in Ethiopia as a Marxist-Leninist unitary state with an ideologically driven state or command economy policy.

make recommendations that lead to improved technical efficiency.

3. The study sites

Batu Degaga Irrigation project is located at 8° 25′ North latitude and 39° 25′ longitude, in the upper Awash River Basin. The elevation of the project area is around 1350 meters (Yusuf, 2004). The total developed irrigable area of the project is 140 ha of which 60 ha is currently under cultivation. Batu Degaga was established by World Vision Ethiopia, a non-governmental organization in 1992. In 1993, a Farmers' Water Users Association was formed and was led by the selected administrative committee from the irrigation project. The numbers of beneficiaries in the project were varying from year to year but now there are 120 members (ibid). Extension advice at Batu Degaga is being provided by six agricultural extension agents permanently residing around the irrigation system. They are graduates of the newly established agricultural training colleges.

Doni irrigation project is located in the upper valley of Awash River Basin and 33 Km North of Sodore Recreational Center. Geographical location of the project is 8° 30′ N and 39°33′ E and the elevation varies from 1240m to 1280m above sea level. It has a different development path from Batu Degaga. Some 30 years ago, a private investor constructed a low head gravity weir in Awash River and about 3 km of main canal for the scheme. During the Derg, the land was nationalized and distributed to smallholders. A Producer Cooperative was established to administer and use the scheme. However, scheme operation and maintenance was not good enough to keep it functional and after few years it almost collapsed. Following the downfall of the Derg, a group of individual farmers who owned land within the boundary of the irrigation scheme started rehabilitating it and requested the assistance of CARE-International in Ethiopia (a non-governmental organization). The request for rehabilitation was accepted in 1994 and the construction was completed in 1997 (ibid). At the time of study, there was no development agent assigned to the irrigation project to provide extension advice, however, Yusuf (2004) wrote that there was one development agent assigned by the Woreda's Irrigation Bureau to assist, advice, organize and monitor the irrigation project activity and the farmers in the association.

The Godino irrigation project is located in East Shewa zone of the Oromia region, Ada Liben Woreda. The water source is a big reservoir. The runoff of the surrounding catchments areas supplying the Wedecha and Belbela streams are made to run to the Reservoir and the water is distributed through canals. Though a Water Users Association does exist, Oromia Irrigation Authority and Woreda authorities control water distribution.

At Batu Degaga and Doni farmers grow vegetables like onions and potatoes. At Godino a mixed farming system consisting of vegetables, namely, chickpea, pea, onions, potatoes and cereals like maize, wheat and teff are practiced.

4. Data collection

The selected small scale irrigation schemes, namely, Doni, Batu Degaga, and Godino, which are located in the Rift Valley of Ethiopia, were chosen due to their relative proximity to the capital, Addis Ababa. Primary data were collected using the household as the unit of analysis. From each irrigation scheme, 50 randomly selected households were beneficiaries of irrigation and another 50 randomly selected households belonged to a control group who did not have access to irrigation. The control group is not far from the irrigation schemes. They are just bordering the irrigable area. Socio economic and production data were collected for the sample households for a year, between March 2004 and February 2005. Production data was used to compute the gross value of production per household.

The area planted was summed across irrigation seasons where applicable. Data on labor, family and hired, was collected for each cropping season by operation and also summed across seasons. The number of corrugated iron sheets of on the roof of the house of the farmer was used as a proxy for capital. Worku G. (1999) used the same methodology. Data were also collected on fertilizer applied, the number of oxen days used for plowing, money spent on seed and pesticides, and the total number of irrigations. Household size and off farm income were collected to give an idea of the household's dependence on irrigation.

The data were collected with funding from the International Water Management Institute (IWMI).

5. Methodology

The study utilizes the stochastic frontier production function, as developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), to estimate technical efficiency.

For a cross section of firms, the stochastic frontier production function is given as:

$$Yi = f(Xi, b) + ei \quad , i= 1,\dots,N \dots\dots\dots..1$$

where Yi is the output of the ith firm, Xi is vector of inputs, and b is a vector of production function parameters. ei is an error term made up of two components such that:

$$ei = vi - ui \quad ....2$$

In equation 2 the error term vi is assumed to be a symmetric disturbance that is independently distributed as N(0, s2v). This error term is thought to exist due to favorable and unfavorable external shocks out of the firms control and also to errors of measurement. It is this part of the error term that makes the frontier stochastic as firms can temporarily be above the frontier if the value of vi is large enough (Aigner et al., 1977).

The error tern ui is assumed to be independent of vi and meets the condition that ui > 0, or is truncated above zero. This error term provides deviations from the frontier. The negative sign in equation 2 along with positive values of ui cause negative deviations from the frontier for each observation. In their original paper Aigner at al.(1977) modeled this error term as a half–Normal and also as an exponential distribution.

In this study the frontier production function is used for cross-sectional data as described by Jandrow et al (1982) to estimate farm level technical inefficiency. The computer software FRONTIER Version 4.1 which gives the opportunity to specify the error term as half-Normal and truncated half-Normal was used to estimate the production function. The production function was specified as:

Value of output = (A, L, F, S, R, O, I, P)

where

A = Total area planted (ha).

L = labor used in person-days

F = Fertilizer applied in kg

S = Amount of money spent on seed (Ethiopian Birr, 1 USD = 8.65 Birr)

R = number of sheets of corrugated iron of the roof of the house (what is the need of including this variable if we are going to take it out of the estimation model.

O = number of oxen days for plowing.

I = total number of irrigations during the year.

P = amount of money spent on pesticides (Birr)

In all the three irrigation centers, average land holding family labor days used in production are higher in the dry land setting than that of the irrigation. However, irrigating farmers use much more hired labor. Output and off farm income are also very high in the irrigation setting as compared to the control group. Table 1 shows the mean values for the collected data.

Table1: Mean values of collected data by irrigation system

	Batu Degaga		Doni		Godino	
	Irrigation	Dry land	Irrigation	Dry land	Irrigation	Dry land
Off farm income (Birr)	187.8	96.2	1,790	1520	422	192.8
Household size	5.3	5.4	3.3	4.6	5.2	4.9
Irrigated land in h (ha)	0.55	1.53	0.44	1.78	0.36	0.67
Family labor days	49.6	83.1	9.2	83.6	80.1	89.8
Hired labor days	276.6	52.8	235	43.2	23.2	26.1
Fertilizer (kg)	255.8	100.8	1,161	37.3	136	253.8
Seed (Birr)	858.2	173	2,988	177	293	305
Iron sheets	**11.4**	4.3	27.4	13.5	30	23
Number of irrigations	27.2	----	61.7	----	15	----
Plowing oxen days	16.6	18.6	14.4	17.4	11.7	18.4
Pesticides (Birr)	459.3	80.1	2008	9.5	50	33.7
Value of output	16,374	4535.7	24,448	3,253	2,662	3294

6. Model Specification

An important issue in this study is the choice of functional form and the distribution of the error term. It is not assumed that the irrigation systems all have the same functional form which makes the comparison of technical inefficiencies somewhat complex. We started with a

general translog functional form and then test whether the equations can reduce to either a partial translog or a Cobb Douglas using a one-sided generalized likelihood ratio test. The chow test is used to determine

whether some of the schemes could be pooled together and thus estimate on equation. The same is done for the dryland data.

The different Chow test showed that the data from Doni and Godino could be pooled together. The likelihood ratio test also showed that the equation for the combined Doni and Godino data could be reduced to a Cobb Douglas. The same test (LR test = 36.4) showed that the half normal distribution of the error term was a better fit. The same result was arrived for the dry land data for Doni and Godino.

The irrigation and dryland data for Batu Degaga is therefore treated separately. Model specification tests for the irrigation data showed that the equation for Batu Degaga was a full translog with a truncated half normal error term.

7. Results

Estimation is done using FRONTTIER Version 4.1, a computer program for stochastic frontier production and cost function estimation, which was developed by Tim Coelli

7.I Production function analysis

7.1.1 Irrigation Settings

7.1.1.1 Doni and Godino together

The combined data for Doni and Godino has a sample size of 93. The variables included in the production function are the natural logarithms of output, land, number of irrigations, seed, fertilizers, pesticides, labor and the number of sheets of corrugated iron (as a proxy for capital) and the interactions of these variables. In the translog model the main variables with their interaction terms are 23 variables while there are 15 variables that are believed to explain inefficiency of farmers.

After some iterations, the likelihood ratio test showed that the Cobb-Douglas production function is the right specification for this data with 7 explanatory variables of the production function and 14 variables that are believed to affect efficiency of farmers. The same test also showed that the half normal distribution of the error term is the better distribution.

The final Maximum Likelihood Ratio estimates of Doni and Godino irrigation schemes combined:

	coefficient	standard-error	t-ratio
constant	3.37	0.64	5.24
land	0.08	0.13	0.58
water	0.06	0.09	0.69
seed	0.34	0.11	3.20
fertilizer	0.28	0.08	3.39
pesticide	0.02	0.05	0.46
labor	0.36	0.10	3.50
roofing	-0.005	0.04	-0.11

The dependent variable of this equation is the natural logarithm of output and all the explanatory variables are in natural logarithm form i.e the model is a double-log model.

FRONTTIER Version 4.1 gives the level of inefficiency of each farmer and the mean efficiency of the system along with the production function estimates. Inefficiency effects (variables that are believed to explain farmers' inefficiency) vary in number from scheme to scheme because variables that don't have any variability were avoided from the model.

7.1.1.2 Batu Degaga

The data for Batu Degaga has a sample size of 51. The variables included in the production function are the natural logarithms of output, land, number of irrigations, seed, fertilizers, pesticides, labor and the number of sheets of corrugated iron (as a proxy for capital) and the interactions of these variables. In the translog model the main variables with their interaction terms are 23 while there are 13 variables that are believed to explain inefficiency of farmers.

The different likelihood ratio tests showed that the production function for Batu Degaga can be represented by a full translog function while the error term has a truncated normal distribution.

The Maximum Likelihood Estimation results of the production function for Batu Degaga irrigation scheme is:

	coefficient	standard-error	t-ratio
constant	0.66	1.42	0.46
land	0.48	1.20	0.40
water	0.49	0.18	2.67
seed	0.19	0.07	2.76
fertilizer	0.03	0.72	0.04
pesticide	-0.40	0.41	-0.96
labor	1.79	0.85	2.09
roofing	0.33	0.51	0.64
landsq	-0.07	0.27	-0.27
fertsq	0.07	0.04	1.81
pestsq	-0.04	0.03	-1.13
laborsq	-0.18	0.17	-1.05
roofsq	-0.04	0.15	0.29
landfert	0.09	0.30	0.30
landpest	-0.04	0.07	-0.58
landlabor	-0.11	0.35	-0.32
fertpest	-0.03	0.09	0.33
fertlabor	-0.04	0.17	-0.22
pestlabor	0.15	0.10	1.50

As was the case for Doni and Godino, elasticity of labor in Batu Degaga irrigation scheme possesses the highest magnitude from among the main factors of production. A unit percentage change in the amount of labor days used will bring about a 1.8 percentage change in the amount of output produced. This change is also statistically different from zero. This implies that labor is not an abundant resource in the irrigation scheme. We can increase output in this irrigation scheme by increasing the supply of labor. Since this labor variable is defined as a labor day, if the farmer increases the number of labor days he or she spent on their farms by one percent, they can increase their agricultural output by 1.8 percent.

On the other hand, if we can somehow increase the water supply of the irrigations and hence increase the number of times farmers irrigate their land by one percent, we can bring about a 0.5 percentage increase in their agricultural production. This coefficient of water is also statistically significantly different from zero.

A percentage increase in the size of land will also bring about a 0.48 percent increase in output. This is in line with many other studies whereby they confirm the very small size of land in Ethiopia being detrimental to agricultural production.

The capital proxy (the number of sheets of corrugated iron of the roof of the house of the farmer) also showed that a percentage change in the capital of the farmer brings about a 0.33 percent change in agricultural output.

Fertilizer and seed are the other factors of production with a positive influence on output. A percentage change in the amount of fertilizer used will bring about a 0.29 percent change in output. A percentage change in seed also brings about a 0.18 percent change on output, though the coefficients of both fertilizer and seed are not statistically significant. Pesticide has an unexpected negative sign.

7.1.2 Dry land Settings

As per the results of the Chow test, the dry land data surrounding Doni and Godino irrigation schemes were estimated together while those around Batu Degaga were treated separately.

7.1.2.1 Doni and Godino dry land together

The combined dry land data for Doni and Godino has a sample size of 100 and the better representation of the data according to the likelihood ratio tests is a Cobb-Douglas production function with a half-normal error distribution. The model has 6 explanatory variables of the production function and 11 efficiency effect variables.

The final Maximum Likelihood Ratio estimates of the model for the dry land agriculture for Doni and Godino combind

	coefficient	standard-error	t-ratio
constant	3.82	0.51	7.54
land	0.23	0.13	1.70
seed	0.60	0.11	5.57
pesticide	-0.02	0.03	-0.77
labor	0.35	0.13	2.71
roofing	0.02	0.02	0.79
oxen	-0.18	0.11	-1.62

In this dry land setting, increases in the usage of factors like labor, seed, land, and capital increases output, though at different percentage increases. A percentage increase in the value of seed increases agricultural output by 0.6 percent. Since close to all farmers reported to use local varieties of seed, this coefficient showed that farmers are not using even local varieties of seed up to their full potential.

As was the case for the irrigated agriculture, labor is not a very abundant resource even for the dry land agriculture. A unit percentage increase in labor still increases output by about 0.35 percent and this elasticity coefficient is statistically different from zero. This may also be because of the small family size of these areas from the national average or it could also be due to the nearby high demand of hired labor by the irrigation farms.

The tiny holding size of land, as was the case for irrigated agriculture, is restricting agricultural output. A unit increase in the size of land increases agricultural production by 0.23 percent and this coefficient is statistically significant. This could be due to the very small size of farmers in the areas, though it is a bit higher when compared with that of irrigating farmers.

Though statistically insignificant, a percentage change in the capital of farmers, as can be seen from the coefficient of the proxy variable, increases output by 0.18 per cent. The statistical insignificance may come from the fact that dry land farming is not capital intensive in Ethiopia.

Farmers seem to use more oxen days on their farm as can be seen from the negative sign of the 'oxen' coefficient. A unit increase in oxen (defined as the number of pairs of oxen used for plowing the land times the number of days they plow) will decrease output by 0.17 per cent. The use of pesticide also has an unexpected negative sign in the production function. However, both the oxen and pesticide coefficients are statistically insignificant.

Batu Degaga Dry land

The dry land data around Batu Degaga irrigation scheme has a sample size of 47. The estimation result showed that the better representation of this data is a translog model with a half-normal distribution of the error term. The five main variables in the production function with their squared and interaction terms make the total variables in the production function to be 16. There are also 11 inefficiency-explaining variables in the model.

The final Maximum Likelihood Ratio estimates for dry land agriculture in Batu Degaga:

	coefficient	standard-error	t-ratio
Constant	13.0	1.57	8.23
Land	2.12	1.12	1.89
Pesticide	0.44	0.23	1.93
Labor	-3.15	0.79	-4.0
Roofing	0.35	0.16	2.17
Oxen	1.45	0.90	1.61
Landsq	0.81	0.21	3.80
Pestsq	0.006	0.15	0.39
Laborsq	0.28	0.14	1.96
Roofsq	-0.09	0.04	-2.38
Oxensq	-0.43	0.34	-1.26
Landpest	-0.09	0.06	-1.49
Landlabor	-0.30	0.30	-1.00
Landoxen	-0.08	0.336	-0.23
Pestlabor	-0.03	0.05	-0.52

Pestoxen	-0.06	0.05	-1.41
Laboroxen	0.23	0.33	0.69

Dry land farmers around Batu Degaga are highly constrained by their size of land. A unit percentage increase in the size of land will bring about a 2.1 % increase in agricultural output, showing the relative scarcity of land in the area.

Labor seems to be deployed excessively on this agriculture. A percentage increase in labor days will bring about a 3.1 percent decrease of output. The redundant use of labor may not be surprising in the face of scarce land resource.

A percentage increase in the number of oxen days brings about a 1.5 per cent increase in output. The coefficient is also statistically significantly different from zero. Increase in the level of pesticide use by one per cent also brings about a 0.4 per cent increase in agricultural output while that of capital brings 0.34 per cent increase.

7.2 Inefficiency Effects

7.2.1 Efficiency of Dry land settings

7..2.1.1 Doni-Godino Irrigation Scheme

There were 14 inefficiency effects that are believed to explain the inefficiency of farmers in Doni and Godino irrigation schemes. The maximum likelihood estimation of FRONTTIER Version 4.1 gives the estimates of these variables with that of the production function. In this computer program, the dependent variable is level of inefficiency (not efficiency). As a result, we expect the variable to have the opposite sign of its effect on the efficiency.

Technical inefficiency effects for Doni and Godino irrigation schemes are:

	Coefficients	standard errors	t-ratios
credit	-0.09	0.19	-0.46
advice	-0.26	0.16	-1.61
offfarm	-0.00004	0.00003	-1.39
hhsize	0.07	0.04	1.89
gender	0.31	0.16	1.91
eduhh	0.03	0.02	1.75
age	-0.01	0.01	-0.87
agesq	0.00006	0.0002	0.38
edumem	-0.05	0.18	-0.28
extension	0.05	0.13	0.35
medslope	0.08	0.13	0.65
steeply	0.06	0.19	0.30
mdummy	0.49	0.21	2.36
tdummy	0.44	0.23	1.88
sigma-squared	0.20	0.03	5.91
gamma	0.0005	0.01	0.04

As can be seen from the negative sign of the coefficients, farmers who get credit within the last three years and who are beneficiaries of agricultural advisory services, perform better in terms of efficiency than those who don't. Since the coefficient on advice is statistically significant, we can say that advice makes a tangible improvement in efficiency of farmers.

Farmers who have higher off-farm income are also more efficient than those who don't. This may be due to the fact that the extra income may enable them to invest on improved technologies. It might also be the case that farmers with high off-farm income, especially those in small local trades, are more exposed to different ideas than those who don't have.

Males are found to be more efficient than females in Doni and Godino irrigation schemes. The coefficient of gender is also statistically different from zero.

Farmers located at the middle and tail locations of the watercourse are less efficient than those at the head reaches. As can be seen from the dummy variable for medium location of farms (mdummy) and tail locations of farms (tdummy), farms at the head reach are more efficient. The coefficients of both of these variables are statistically significantly different from zero. The other inefficiency variables were found to be not statistically different from zero.

The mean efficiency of farmers of Doni and Godino irrigation schemes is 55.6 %. That is we can increase output of these farmers by 44.4% by just re-allocating their input use.

Percentages of Technical Efficiency Estimates for Doni and Godino Irrigation Schemes Together

Range of efficiency levels	Frequency
< 0.3	0
0.3 to 0.39	17
0.4 to 0.49	28
0.5 to 0.59	17
0.6 to 0.69	10
0.7 to 0.79	9
0.8 to 0.89	5
0.9 to 0.99	3
1	4

7..2.1.2 Batu Degaga

The model for this irrigation scheme has 12 inefficieny-explaining variables.

Mean efficiency of the irrigated scheme is 76 %. That is without extra input, re-allocations of the farmers' resources can increase output by 24%.

Percentages of Technical Efficiency Estimates for Batu Degaga Irrigation Scheme

Efficiency Range	Frequency
< 0.3	1
0.3 to 0.39	1
0.4 to 0.49	6
0.5 to 0.59	4
0.6 to 0.69	3

0.7 to 0.79	5
0.8 to 0.89	16
0.9 to 0.99	15
1	0

7.2.2 Efficiency of Dry land Farmers

7.2.2.1 Doni and Godino dry land farmers:

There are 11 inefficiency variables in this model. The highest level of efficiency of farmers is exhibited in these areas. The mean efficiency of these farmers is 79.8%. However, we can increase the output of the farmers by 20.1% with the same level of inputs that farmers are using.

Percentages of Technical Efficiency Estimates for Dry Land Farmers Around Doni and Godino

Efficiency Range	Frequency
< 0.3	2
0.3 to 0.39	0
0.4 to 0.49	6
0.5 to 0.59	4
0.6 to 0.69	8
0.7 to 0.79	8
0.8 to 0.89	50
0.9 to 0.99	22
1	0

7.2.2.2 Batu Degaga dry land Areas

The final model for these farmers includes 11 inefficiency-explaining variables. The mean efficiency of the farmers is 65.6%, implying that we can increase agricultural output of the farmers by 34.4% by reallocating their resources.

Percentages of Technical Efficiency Estimates of Dry Land Farmers in Batu Degaga

Efficiency Range	Frequency
< 0.3	0
0.3 to 0.39	7
0.4 to 0.49	2
0.5 to 0.59	13
0.6 to 0.69	7
0.7 to 0.79	3
0.8 to 0.89	5
0.9 to 0.99	8
1	2

7.2.3 Comparison of Efficiency between the irrigation schemes and rainfed agriculture

In two irrigation schemes dry land farmers happened to be more efficient than irrigation farmers with respect to their own frontiers.

In Doni and Godino areas, the efficiency of irrigation farmers is 55.6 %. However, the mean efficiency of farmers with no access to irrigation around these irrigation areas is 79.8 %. This may be due to the fact that low level of output of the dry land farming system is forcing the farmers to allocate the small resources they have more efficiently than the irrigation farmers. The difference between the dry land and irrigation farmers in these areas is more than 24 percentage points.

The mean efficiency of farmers in Batu Degaga irrigation scheme is 76% while dry land farmers around this scheme are 65.6 % efficient. The difference in efficiency of these two groups of farmers is more than 10 percentage points.

But we should take note of the fact that the two types of farmers are facing two different frontiers. The irrigators are facing a higher frontier than the dry land farmers and are on average more far from their frontier while dry land farmers are closer to their low frontier. That is to say the availability of water for irrigators has pushed their frontier outwards and made them productive. And yet, the high inefficiency of these farmers indicates that there is even more potential to be exploited and the potential presented by water isn't yet exploited.

To compare the frontiers of irrigators and dry land farmers, points on the frontier in each system are selected, specifically the average of the logarithmic transformations that were used to estimate the frontiers. These averages are then converted back to original, non-logged, levels to give comparable input combinations on the frontiers of each system. Makombe et al, 2001, used this methodology. The results of this evaluation show that Doni and Godino irrigation schemes require 0.77 ha of land, 26.6 days of irrigation, Br 706.3 worth of seed, 320 kg of fertilizer, Br 202 worth of pesticide, and 114.4 labor days to produce Br 5, 271 worth of output. On the other hand the dry land farmers surrounding these two irrigation schemes require 1.22 ha of land, Br 194.4 worth of seed, Br 4.9 worth of pesticide, 97.5 labor days, and 15.2 pairs of oxen plowing days to produce Br 2,591 worth of output. This implies that irrigators and dry land farmers don't face the same frontier and the frontier for irrigators is much higher than that of dry land farmers.

In Batu Degaga, irrigation requires 0.92 ha of land, 22.2 days of irrigation, Br 299 worth of seed, 148.4 kg of fertilizer, Br 181.3 worth of pesticide and 244.7 labordays to produce Br 8,103 worth of output; while dry land farmers in this area are required 1.3 ha of land, Br 22.2 worth of pesticide, 121.5 labor days and 14 pairs of oxen plowing days to produce Br 4,024 worth of output. These show that irrigators face a higher frontier than dry land farmers.

7.2.4 Marginal Productivities

To compute for marginal Productivity of inputs we first non-linearize the estimated production function and take the first derivative of output with respect to the specific input for which its marginal productivity is to be determined.

For Doni and Godino irrigation schemes together, the estimated production function is:

$$Lny = 0.34 + 0.78\ln(land) + 0.6\ lnwater + 0.34lnseed + 0.28lnfert + 0.21lnpest + 0.36lnlabor - 0.48lnroof$$

$$Y = 0.34(land)^{0.78}(water)^{0.6}(seed)^{0.34}(fert)^{0.8}(pest)^{0.21}(labor)^{0.36}(roof)^{-0.48}$$

Taking the first derivative of Y with respect to each input and evaluating the resulting equation at the mean of regression variables gives the marginal productivity of each input.

For the dry land farming around Doni and Godino

Y = 0.38(land)0.23(seed)0.6(oxen)-0.18(pest)-0.2(labor)0.35(roof)0.18

Marginal productivity of inputs in Doni and Godino areas, based on frontier regression estimates:

	Doni Godino Irrigated		Doni Godino dry land	
Attribute	Level	marginal productivity	Level	marginal productivity
Value of output	5,271		2,591	
Land	0.77	32,529	0.2	18.6
Irrigations	27	687	---	
Seed	705	15.8	194	0.05
Fertilizer	320	78	---	
Pesticide	202	32.1	5	-0.66
Labor	114	97.6	98	0.05
Oxen	---		14	-0.2

All inputs have higher marginal productivity in the irrigated agriculture compared with dry land agriculture. The result showed that any additional money spent on increasing land holdings, or to increase the number of times farmers can irrigate their land, to supply fertilizer and pesticide have high return in the irrigation schemes of Doni and Godino. The irrigation schemes can also accommodate more farmers or the existing farmers should spend more time on agriculture since an additional laborday spent on the farm will bring about a high return.

8. Conclusion and recommendation

8.1 Conclusion

The paper tried to analyze the level of efficiency of farmers between irrigated and dry land farmers based on three irrigation schemes in Ethiopia. These schemes are Doni, Godino and Batu Degaga irrigation schemes.

The empirical findings showed that inefficiency of farmers prevail in Ethiopia very significantly, a result which is in conformity with other efficiency studies of Ethiopian farming by Abay and Assefa (1996), Abrar (1998), Croppenstedt and Abbi (1996) and many others. The contribution of this paper in efficiency studies of Ethiopian Agriculture is that it compares the efficiency levels of irrigation and dry land farming. Though, there are very few irrigation schemes in Ethiopia, much inefficiency is exhibited in the existing schemes. In fact in two of the irrigation schemes, among three studied, their surrounding dry land farmers are more efficient than the irrigating farmers, compared of course, with respect to their own frontiers.

Both for the combined data for Doni and Godino as well as Batu Degaga irrigation scheme, among all the explanatory variables, labor has the highest elasticity of output. In Doni and Godino, a one-percentage change in the amount of labor days will bring about a more than 0.36 percent change in output. We can also increase agricultural production in these two irrigation schemes by more than 0.28 percent if we increase fertilizer use by one percent. A percentage change in the value of seed also brings about a more than 0.34 percent change in output. In Batu Degaga, a unit percentage change in the amount of labor days used will bring about a 1.8% percentage change in the amount of output produced. On the other hand, if we can somehow increase the water supply of the irrigations and hence increase the number of times farmers irrigate their land by one percent, we can bring about a 0.5 percentage increase in their agricultural production. A percentage change in seed also brings about a 0.18 percent change on output. These coefficients are also statistically significantly different from zero.

In terms of explaining the inefficiency of farmers, agricultural advices, existence of off-farm income and the location of farms on the watercourse appeared to have significant influence on the efficiency of farmers. Farmers at head reach are more efficient than farmers at the middle and tail locations of the watercourse. Males also happened to be more efficient than females. The coefficients of these variables are statistically significantly different from zero. Moreover, availability of credit, number of years of education of the head of the household (in Batu Degaga only), existence of a member of the household who completed primary school, age of the head of the household and the slopes of farmlands have their expected signs, though statistically insignificant.

The empirical findings also showed that there is significant inefficiency in the sampled irrigation schemes. The mean efficiency of farmers of Doni and Godino irrigation schemes is 55.6 %. That is we can increase output of these farmers by 44.4% by just re-allocating their input use. Mean efficiency of the Batu Degaga irrigation scheme is 76 % implying that without extra input, re-allocations of farmers' resources can increase output by 24%. In Doni and Godino irrigation schemes dry land farmers happened to be more efficient than irrigation farmers with respect to their own frontiers. The dry land farmers nearby these schemes have a mean efficiency of 79.8 %. However, irrigators are more efficient than dry land farmers in Batu Degaga area.

8.2 Recommendations

In the face of resource constraint of many farmers and their high inefficiency levels, much attention should be given in affirming that farmers are using to the best of the little resource they have. Many farmers especially in the irrigated agriculture are performing way far from their frontier. In the irrigated agriculture, government and other relevant bodies should facilitate credit facilities since those farmers who were beneficiaries of credit are much closer to the frontier. Agricultural advices should also be given to farmers in a concerted manner since this variable was found to significantly affect the level of efficiency of farmers. Education has also a positive impact in terms of farmers' efficiency. Therefore government should intensify its efforts to expand education to the rural sector. The fact that families where there is at least one member who finished primary school are more efficient further justifies the need for expanding education. Activities that create more off-farm income to the rural sector are also things to be encouraged since off-farm income happens to increase the efficiency of farmers.

Since the marginal productivities of inputs in the irrigation schemes are very high, attention should also be given to increase the availability of these inputs. Government and other relevant bodies should try hard to bring more land to irrigations since the marginal productivity of land of the irrigated agriculture is tremendous. The irrigation schemes of the lowland that follows the Awash River should find ways to attract more labor from the highlands where labor is expected to be abundant. The weather condition of this area along with the high demand for hired labor by the neighboring large commercial and state farms has made it difficult for the smallholders to obtain as much labor as they want. The marginal productivity of labor in these schemes is very high. Fertilizer, pesticides and seeds should also be better supplied to the irrigation schemes since the marginal productivity of these inputs happened to be very high.

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