Advances in Agricultural Science

Volume 6 (2018), Issue 04, 72-84

Journal homepage: www.aaasjournal.org

ISSN: 2588-3801

Research Article

Open Access

Economic efficiency of water use in the small scale irrigation systems used in vegetables production in Koulikoro and Mopti regions, Mali

Abdoulah Mamary Kane [1, 2, 3*], Job Kibiwot Lagat [1], Jackson Kipngetich Langat [1], Bino Teme [2], Samuel Ngunjiri Wamuyu [1]

[1] *Egerton University, Njoro, P.O Box 536 20115, Egerton, Kenya.*

[2] *Institut d'Economie Rurale (IER), P.O Box 258, PROMISAM/MSU, Bamako, Mali.*

[3] *University of Segou (Agri & Livestock, Technologies), Mali.*

ARTICLE INFO

Article history:

Received: March 23, 2018
Revised: July 22, 2018
Accepted: July 27, 2018
Available online: December 15, 2018

Keywords:
Economic efficiency
Irrigation systems
Vegetables production
Water
Smallholders
Mali

* Corresponding Author;
E. Mail:
kanemali2003@gmail.com

ABSTRACT

Malian households depend, in majority, on rain-fed agriculture for their food production. Overreliance on rain-fed agriculture limits the production output due to unreliable rainfall in the country. To mitigate this, the government has invested in rehabilitation of irrigation schemes to reduce dependence on rainfall. Through appropriate irrigation technologies and improved agronomic management practices agricultural productivity will be increased. This study determines the contribution of different irrigation systems to produce vegetables on household welfare in rural communities. The objective of the study was to contribute to improved livelihood of smallholder farmers in rural areas by use of irrigation systems in vegetables production. Three localities corresponding to two specific climatic regions favorable to vegetable crops production in Mali (Baguineda, Kati, Koulikoro region and Mopti region) was the study area. This study was guided by the production theory. Primary data was collected from 273 farmers selected proportionately from four wards (Fanafiecoura and Tieman, in Koulikoro region and Mopti and Dialango, in Mopti region) using face-to-face interviews. Secondary data from literature reviews was also used. Descriptive statistics and DEA functions were used for analysis. The Statistical Package for Social Scientists (SPSS), Stata and Excel programs were used for analysis. This study found that the irrigation systems as used in production of the three main crops to be characterized by inefficiency. Drip and sprinkling irrigation systems was relatively more economically efficient as compared with Californian system. The use of drip, sprinkling and Californian irrigation systems lead to greater benefits as compared to costs. The excess benefit (compared to costs) is realized more with drip followed by sprinkling and the third being California irrigation system. This study recommends more training and capacity building to the farmers in the study area with an aim of reducing their levels of inefficiencies in horticultural crop production. Farmers should be supported to adopt the use of drip, sprinkling and Californian irrigation systems which lead to greater benefits as compared to costs. Drip, sprinkling and Californian irrigation systems present a good opportunity for superior technical efficiency in vegetable production. These irrigation technologies should be promoted.

Introduction

Most Sub- Saharan African countries are characterized by low agricultural productivity. One of the reasons for poor production is that African agriculture is predominantly rain fed, which is in most cases unreliable resulting in poor yields and the changing weather conditions would further exacerbate the situation, exposing smallholders to negative impact of climate change (Todaro, 2012). It is becoming increasingly evident that required food supplies cannot be met by rain fed conditions alone (PCDA, 2009). In Mali, the economy dependents on agriculture, that contribute to 36 percent of income derived from cereal, vegetable crops, cotton and sugarcane (National Report Ministry of Agricultural, 2013).

Agricultural production in Mali is beset by a number of challenges arising from climate change. Some of the most visible consequences are the declining groundwater from the months of January to February which comes at a crucial time for horticultural crops and this limits the growing of fruits and vegetables in several localities. The immediate impact is a reduction in crop yield by up to 50 percent in rain fed agriculture (Todaro, 2012).

Due to sinking water levels, the use of manual pumps in deep wells in some areas is no longer sustainable. It has been argued that one strategy which would be used to mitigate water scarcity and dependence on rain fall is irrigation. Indeed (Pinstrup and Derill, 2011, Hussain, 2004), revealed that investing in small scale irrigation schemes is one of the strategies to improve production levels especially for small holder farmers. The general belief is that irrigated agriculture limits crops failure, external shocks and increases yield thus leading to better food security (Nokuphiwa *et al.*, 2014) (FAO, 2010).

Malian government has over the years endeavored to expand the country’s irrigation infrastructure in order to improve agricultural production and enhance food security. This had led to expansion of the total irrigated area in the country. Before the year 2008, Dougabougou and Siribala sugar cane plantations was the only irrigated large scale land in Mali. Currently the government of Mali is implementing food sustainability for smallholder farmers through a long term national program for food security by 2025. This may be attained by targeting small scale irrigation systems to increase production.

The types of irrigation technologies that are practiced in Mali are: drip irrigation, Californian system, sprinkling system and gravity system. The Drip irrigation technology consists of bringing water under pressure in a system of pipelines. This water is then distributed in drops in the field by a large number of gutters distributed all along rows of plants. This irrigation system is used to grow tomato, onion, shallot (Allium fistulosum), banana, papaya and oranges.

Californian irrigation system is a network of PVC pipelines buried that permits to decrease losses by infiltration. It routes water on a parcel moved away of the source of pumping or having an irregular topography and follow the level of triage and of row without addition or manipulation of hoses. Water is lifted from the surface or the underground water source and distributed to plants into furrows. With this system, crops are arranged on ridges. This system is mainly used for vegetable crops such as shallot and onion.

The Sprinkling irrigation system; the technique of irrigation by aspersion is conceived on the model of the natural rain. Water is driven back under pressure in a network of conducts and then it is distributed by the rotary aspersers under the form of artificial rain. It is practiced on commercial farms on high value crops such as fruit trees, coffee, sugar cane and horticultural crop, the potato.

Methods

Study area

Mali is a country whose economy is based on the primary sector (agriculture, livestock, fisheries and forestry), which accounts for nearly 36% of GDP and is the main source of income for at least 80% of the population. In addition, the sector contributes about 40% of export earnings.

Mali's population is estimated at 14.5million (2009) with an average density of 11.7 inhabitants / km ², which varies from 20 in the South (regions, Koulikoro, Kayes, Segou, Sikasso, Mopti and Gao) and less than 1 inhabitant / km ² in the north (Tombouctou and Kidal regions). The average annual growth rate of GDP over the past decade is about 5% and the rate of population growth for the same period was 3.6%. The GDP per capita is currently estimated at U.S. $ 693 (U.S. $ 1 = 400 f CFA).

In Mali, the bulk of agricultural production is dependent on rainfall while the country has land and water resources adequate for the development of agricultural production from irrigation. During rain, the country has considerable water and land resources adequate for the development of agriculture through irrigation (IER, Annual Report, 2010, Hautamäki *et al.*, 2009).

The study was carried out in Baguineda, Koulikoro region. Baguineda is located 30 km from Mali's capital city (Bamako). Potato is the main crop produced in Kati zone located at 15 km from Bamako city. This zone supplies potatoes to the population of Bamako District. Manual irrigation is the most common practice used by farmers to distribute water to crops with watering devices such as watering cans, calabashes and buckets. The introduction of sprinkling irrigation system will facilitate and reduce irrigation time and labor.

In Koulikoro region, the main irrigated crop after rice is tomato in Baguineda zone. From 1964 to 1994, there existed a tomato concentrate factory in this area. Currently, farmers sell their products in Bamako city. Farmers in Baguineda zone use the wells as water source for manual irrigation systems using watering cans and buckets to distribute water to crops. The competitiveness and diversification program of agriculture (PCDA) successfully used drip irrigation on the fruit trees. Table 1 presents the total area and average yields of the different irrigated crops in Mali.

The major crops (tomato, potato and shallot: Allium fistulosum) and cropping pattern depends on water quality, soils, agro-ecological zones and principally by local preferences (DNSI, 2010, Kelly, 2009). Figure 1 shows the location of the study area.

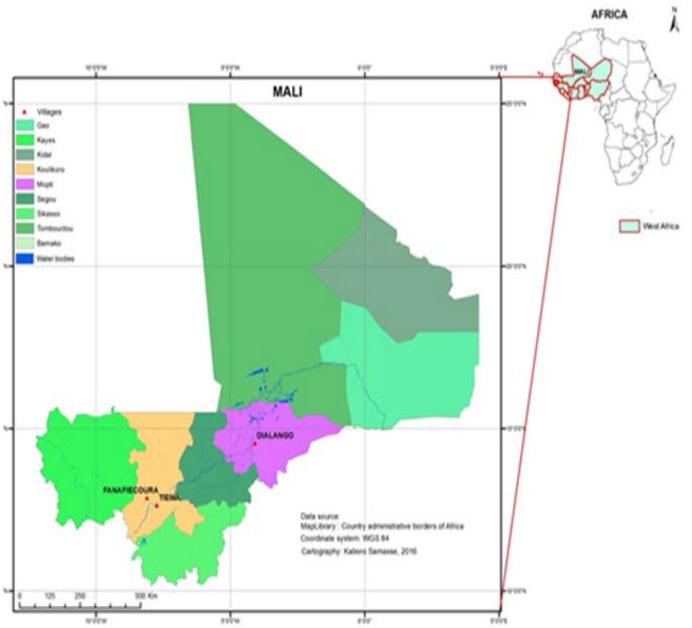

Figure 1. Maps showing location of the Study Area: (Source: Annual report PIB, 2011).

Population

The population in this study comprised of small holder farmers in Koulikoro and Mopti regions in Mali. These were farmers who held at most 1 hectare of land for their vegetable farming using small scale irrigation systems such as drip, sprinkling and Californian. The distribution of the population in the different areas of the study is as shown in Table 2.

Sample size determination

Table 1. Means of area and yield of the major irrigated crop in the two last agricultural campaigns (2008-2009 and 2009-2010) in Mali.

Number	Crop	Area (ha)	Yields (Kg/ha)
1	Citrus fruits	25475	14805
2	Banana	20465.88	24335
3	Shallot	13726.27	19258.5
4	Maize	10317.75	1708.5
5	Onion	6297.26	15588.5
6	Potato	5419.28	23131
7	Lettuce	3160.5	12602
8	Okra	2932	8449
9	Tomato	1824.34	16635.5

Table 2. The location of study area

Sites/Villages	Localities	Regions/Counties
Tieman	Baguineda	Koulikoro
Fanafiecoura	Kati	Koulikoro
Dialango	Mopti	Mopti

Source: (DNSI, Report RGA, 2005, Kelly, 2008)

Table 3. Sample for the Survey

Enterprises	Different Technologies		Irrigation	Population	Sample size	Proportion (%)	Location
	T_1	T_2	T_3				
Tomato	31	31	31	3923	93	34.0	Tiema
Potato	30	30	30	2727	90	33.0	Fanafiecoura
Shallot	30	30	30	3549	90	33.0	Dialango
Total	91	91	91	10,200	273	100.0	

Source: (DNSI, Report RGA, 2005, Kelly, 2008); Shallot or *Allium fistulosum*

Table 4. Description of variables used in first stage analysis

Output (Yields)	Mean	Standard Deviation
Tomatoes	37,557,206.00	18,292.68
Potatoes	34,455,091.00	13,683.54
Shallots	112,008,935.00	52,093.02
Total	184,021,232.00	28,023.08
Inputs (Cost item)		
Seed	433,305.20	24,608.04
Manure	115,248.34	1,080.12
Fertilizers	186,667.40	2,624.67
Pesticides	113,247.64	4,478.34
Labour	338,542.90	6,809.98
Transportation	121,348.31	471.40
Other costs	3,505.75	108.01
Totals	1,311,865.54	5,740.08

The research design used in this study was a survey. The target population comprised of all the small scale farmers in the selected regions. The sampling technique employed was multistage sampling. Data was collected using a structured questionnaire. A total of 273 respondents were interviewed as derived from the equation below.

$$n = \frac{K^2 P(1-P)}{D^2}$$ (Kothari *et al.*, 2004)

Confidence level (K) (Z-value) 95% (2-tail) = 1.96;

Expected proportion in population (P) (50% most conservative);

Acceptable margin of error in percent (D) which is 9.5%, hence

$$n = \frac{1.96^2 0.5(1-0.5)}{0.095^2}$$

n = 273

Sampling procedure

A Multistage sampling procedure was used to select 273 farming households of local irrigation scheme in the three regions. The first stage was to purposely select three regions; Fanafiecoura, Tieman and Dialango on the basis of the fact that they are within the area mapped for vegetable crops and the incidence of irrigation systems that is already taking place. The second stage involved the use of cluster sampling where the sampling frame was separated into two clusters with one cluster being the vegetable crops integrated farm households using small scale irrigation system and the other cluster was the control group composed of vegetable farmers not engaged in small scale irrigation system. Random sampling was used in which a representative sample was selected from each cluster. Using a structured questionnaire, a total of 273 respondents were interviewed. Table 3 shows the distribution of sampled respondents.

The sample of 273 people in three (3) localities (Tiema, Fanafiecoura and Dialango) was selected for the survey. The different irrigation technologies likely T_1 (Drip irrigation system), T_2 (Sprinkling) and T_3 (Californian irrigation system) were evaluated in this study. The base for the sample size was according to the population of the smallholder farmers in the three major locations.

Data collection and data sources

Primary and secondary data was collected for the study. Structured open ended and close ended questionnaires were used to collect primary data. The questionnaires were administered to the farmers by enumerators. Data that was collected included: irrigation technologies, gender issues, household size, farm size, age, literacy, farming experience, livestock ownership, extension, soil type, amount of water, residues, slope, distance from Homestead, labor, income levels and the off farm income.

To determine the economic efficiency of water use in the small scale irrigation systems, the Data Envelopment Analysis (DEA) was used. The appropriate model showing the water use efficiency in production and profitability. DEA analysis does not only determine the efficiency rate of a system, but also recommends target values for inputs and outputs responsible for inefficiencies within a system. The original work by Charnes, Cooper and Rhodes (1978) is attributed to have coined the term Data Envelopment Analysis (DEA) and the development of the dual pair of linear programming method into the equivalent ratio form (popularly known as the CCR model). This development provided a basis for analysing efficiency (Cooper *et al.,* 2011; Ding *et al.,* 2015).

DEA is a non-parametric approach to generate an envelopment frontier using well positioned data points. DEA model helps in the analysis relative efficiency of production units. DEA is preferred over other methods of efficiency analysis due to its ability to include multiple inputs and outputs in its calculations. Unlike many stochastic frontier analyses, DEA generates a single scalar value in its measure of efficiency and does not require any specification of functional forms. The DEA input-oriented CRS and VRS models are used to obtain the technical efficiency scores. The efficiency scores obtained from the first stage of the DEA are taken as the dependent variables in the subsequent stage of the Tobit model. In the Tobit regression models handles dependent variables that are constrained at particular limits (Cooper et al, 2010; Macdonald & Moffitt, 2009). Tobit model is an extension of profit analysis. It is a form of censored regression model (Yu *et al.,* 2012).

This procedure allows for the evaluation of economic water use efficiency, economic viability and technical efficiency irrigation technologies. The Tobit model is defined as follows:

$$y = \begin{cases} y^* & \text{if } y^* > 0 \\ 0 & \text{if } y^* \leq 0 \end{cases}$$

$$y_i^* = \beta x_i + \varepsilon_i, \varepsilon_i \sim N(0, \quad \sigma^2)$$

where, y is the dependent variable (the DEA efficiency score), y* is the latent variable, β is a vector of unknown coefficients which determine the relationship between the independent variables and the latent variable and X_i is a vector of independent variables. The model assumes that there is an underlying stochastic index equal to $\beta X_i + \varepsilon_i$ observable only when it is positive (Macdonald & Moffitt, 2009).

The data envelopment analysis (DEA) method is used in analyzing production and profitability efficiencies. The model is a mathematical programming method that has the ability to analyze dual output scenario. This method of analysis however does not consider influence of errors in measurement and other noise in the data (Coeli, 1995). The method is preferred due to its ability to simplify the functional form of the frontier and the distributional form of u_i (Coeli, 1995). The efficiency in production within one firm is measured relative to the efficiency of all the other firms.

$$\text{Min}\theta_j$$

$$\theta_i x_{jm} \geq \sum_{k=1}^{k} x_{km}\lambda_{jk} \text{ for all m}$$

$$\sum_{k=1}^{k} y_{ki}\lambda_{jk} \geq \mu_{ji} \text{ for all i}$$

$$\lambda_{jk}\theta_j \geq 0$$

Where m represents the resources used so that x_{jm} is the amount of productive resources m used by DMU j and x_{km} is the amount of productive resources m used by each of the other DMU k. Within the proceeding equation, i represents outputs so that y_{ji} represents the amount of output i produced by DMU j and y_{ki} is the amount of output i produced by each of the other DMU k. Linear programming technique provides an optimal set of weights denoted by λ_{jk} that satisfy the m × i constraints and give an efficiency coefficient denoted by $0 \geq \theta j \geq 1$. The model weight provides an indication about extent of inefficiency for each DMU (Coeli, 1995).

Charnes et *al* (2010) and Sarkar (2013) has used the model with an orientation of inputs, assuming constant returns to scale (CRS). Banker et *al*. (2009) used the model with an orientation on variable return to scale. The CRS is the most commonly used method among the two.

Profitability efficiency may also be analyzed with the use of Generalized Leontef (GL) as well as the Translog functional forms. These models have been designed to overcoming the shortcoming arising from restrictive nature of the Cobb-Douglas model. These models have a disadvantage of inability to control high levels of multicollinearity and low levels of degrees of freedom. The GL model is not popular in the estimation of efficiency frontiers despite its great popularity in the estimation of cost functions and input demands (*Mbaga et al.,* 2010).

The input oriented Data Envelopment Analysis (DEA) model based on Variable Returns to Scale (VRS) assumption will be used as outlined by *Cinemre et al.,* (2009). The model generates optimal input/output scenarios that minimize input for each production process, thus helping estimate efficiency (Coelli 1998). The efficiency of a firm consists of two components (technical efficiency and allocative efficiency, which gives an implication of the firm's ability to use the inputs in optimal proportions). These two measures (combined) provide a measure of cost efficiency or economic efficiency. According to Farrell (2000) the most efficient firm should have a measure of one (1) on the frontier. The lower the efficiency the lower the coefficient measure.

For each household, a measure of the ratio of all inputs, uy_i/vx_i will be computed, where u is an M×1 vector of output weights and v is a K×1 vector of input weights. To select optimal weights, the mathematical linear programming problem is specified as:

$$max_{u,v}(uy_i/vx_i),$$

Subject to

$$\frac{uy_i}{vx_i} \leq 1, i = 1,2, \dots, N,$$

$$u, v \geq 0.$$

This will entail finding the values of u and v such that the efficiency measure of the i-th household is maximized, given the constraint that all efficiency measures must at most be equal to unity. The above model however, gives an infinite number of solutions and an additional constraint $vx_i = 1$ is necessary to address the problem. The linear programming model will thus be modified as below:

$$max_{\mu,\vartheta}(\mu y_i/\vartheta x_i),$$

Subject to

$$vx_i = 1$$

$$\frac{\mu y_i}{\vartheta x_i} \leq 1, i = 1,2, \dots, N,$$

$$\mu, \vartheta \geq 0,$$

where the notation for the weights have changed to reflect the transformation giving rise to multiplier form of the linear programming model. Duality in linear programming can subsequently be employed to derive an equivalent envelopment form of the LP problem as below:

$$\min_{\theta,\lambda}\theta,$$

Subject

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0,$$

where θ is a scalar and λ is an N×1 vector of constants. The value, θ represent the household's efficiency score. The efficiency score is less or equal to unity, with unity indicating a point on the frontier and hence a technically efficient household (Farrell, 2000). Efficiency score for each of the household in the sample will be determined by solving the LP problem N times. The efficiency score so computed will be on a constant return to scale (CRS) assumption. To incorporate the variable return to scale (VRS) assumption, an additional convexity constraint $N1'\lambda = 1$ will be added to the above LP model. The ultimate LP model that will be estimated will be as below:

$$\min_{\theta,\lambda}\theta,$$

Subject

$$-y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0,$$

where N1 is an N×1 vector of ones.

Results

This study sought to evaluate the economic efficiency of water use in the small scale irrigation systems. The use of Data Envelopment Analysis (DEA) was employed in analyzing water use efficiency in production and profitability. On the onset of this modeling, specification of variables used in first-stage and second-stage DEA analyses is done. First-stage analysis consists of seven inputs and one output and second-stage includes the exogenous variables that are expected to have some impact on the efficiency of irrigation farming in the study area.

Measurement constructs

In order to be able to profoundly measure the technical efficiency of irrigation system using the DEA technique, it is required that the data set includes clearly the identified production units (crops) inputs and outputs. The individual irrigation systems being evaluated must be comparable in the sense that they utilize the same types of inputs to produce the same types of output (Odeck, 2009).

A discussion of the output, inputs and exogenous variables relevant for this study is provided below. Following Coelli *et al.,* (2005), the first stage analysis is further subdivided into traditional inputs and outputs, while the second stage analysis is split into exogenous/environmental variables.

The term traditional inputs include the factors of production, which are the resources used for production and the output obtained. In this study, seven inputs and one output making a total of eight items are used. A total of 270 DMUs were used in this study (the DEA convention that the minimum number of DMUs should be greater than 3 times the number of inputs plus outputs {270 > 3 (7 + 1)} has been maintained). According to Asmild *et al.,* (2004), if this rule of thumb is not met, the DEA results will be biased and questionable. Put simply, the model may produce a large portion of the DMUs that will be identified as efficient and decrease discriminating power, hence giving misleading results.

An average farmer produced vegetables of FcFa. 184,021,232.00 values distributed as tomatoes (37,557,206.00), potatoes (34,455,091.00) and shallots (112,008,935.00) as shown in Table 4.

The average seed cost in the production of the selected three crops (potatoes, tomatoes and shallots) in this study was noted to be FcFa. 433,305.20 with a standard deviation of FcFa. 24,608.04. an average household in the study area was spending about FcFa. 115,248.34 On manure with a standard deviation of FcFa. 1,080.12. Households in the study area spent an average of FcFa. 186,667.40 on fertilizers with a standard deviation of FcFa. 2,624.67. Pesticides were costing farmers an average of FcFa. 113,247.64 with a standard deviation of FcFa. 4,478.34. Households in the study area incurred a cost of FcFa. 338,542.90, FcFa. 121,348.31 and FcFa. 3,505.75 on labour, transportation and other costs with a standard deviation of FcFa. 6,809.98 FcFa. 471.40 and FcFa. 108.01, respectively.

Unlike first stage analysis that results in efficiency scores for all the selected irrigation systems, this stage is used to differentiate traditional inputs from other relevant variables that are expected to have an impact on the efficiency of the crop production systems. Such variables are referred to as 'exogenous' factors that influence the efficiency and are out of the farmers' control. Put simply, second stage variables are measured by making a regression of coefficients that are adjusted to the efficiency scores that tally with the analyzed factors (Coelli *et al.,* 2005). Hence, the cost of water and energy are the aforesaid variables.

An average farmer spent about FcFa. 183,411.48 (with a standard deviation of FcFa. 7,514.77) on exogenous variable costs on production of tomatoes, potatoes and shallots using various irrigation methods as shown in Table 5.

The average energy cost in the production of the selected three crops (potatoes, tomatoes and shallots) in this study was FcFa. 148,643.45 (with a standard deviation of FcFa. 12,559.24). An average household in the study area spent about FcFa. 34,768.03 on water costs (with a standard deviation of FcFa. 2,470.30).

Table 5. Description of variables used in second stage analysis

Exogenous/environmental variables	Mean	Standard Deviation
Energy cost	148,643.45	12,559.24
Water cost	34,768.03	2,470.30
Totals	183,411.48	7,514.77

Table 6. Correlation coefficient analysis between tomatoes yield and inputs

Cost item	Pearson's Correlation Coefficient (r)	P-value
Seed	0.380*	0.022
Manure	0.189	0.582
Fertilizers	0.341*	0.000
Pesticides	0.242*	0.038
Labour	0.427*	0.008
Transportation	0.216*	0.031
Other costs	0.112	0.420

Table 7. Correlation coefficient analysis between potatoes yield and inputs

Cost items	Pearson's Correlation Coefficient (r)	P-value
Seed	0.259*	0.018
Manure	0.218*	0.024
Fertilizers	0.203*	0.022
Pesticides	0.189*	0.048
Labour	0.374*	0.001
Transportation	0.072	0.528
Other costs	0.063	0.558

Table 8. Correlation coefficient analysis between potatoes yield and inputs

Cost item	Pearson's Correlation Coefficient (r)	P-value
Seed	0.117	0.282
Manure	0.148	0.185
Fertilizers	0.366*	0.014
Pesticides	0.251*	0.032
Labour	0.330*	0.025
Transportation	0.057	0.344
Other costs	0.156	0.213

Table 9. Average DEA efficiency scores across the irrigation systems

	Output-oriented VRS		Output-oriented CRS	
Irrigation system	Mean	Std. Deviation	Mean	Std. Deviation
Drip	0.90	0.019	0.20	0.029
Sprinkling	0.75	0.015	0.17	0.026
Californian	0.64	0.011	0.14	0.026
Total	0.76	0.105	0.17	0.027

F-Ratio (VRS) = 532.35, F-Ratio (CRS) = 4.891, Critical F-Ratio (2,267) = 4.256, P-Value (VRS) = 0.000, P-Value (CRS) = 0.037.

Table 10. Average DEA efficiency scores across the crop enterprises

	Output-oriented VRS		Output-oriented CRS	
Irrigation system	Mean	Std. Deviation	Mean	Std. Deviation
Tomatoes	0.78	0.14	0.19	0.04
Potatoes	0.75	0.13	0.13	0.03
Shallots	0.76	0.13	0.18	0.03
Total	0.76	0.13	0.17	0.03

F-Ratio (VRS) = 0.041, F-Ratio (CRS) = 3.506, Critical F-Ratio (2,267) = 5.143, P-Value (VRS) = 0.96, P-Value (CRS) = 0.09

Initial Data Assessment

In order to ensure that crop yields per hectare (outputs) relate to the inputs (Seeds, manure, fertilizers, pesticides, labour, transportation, materials/equipment, installation costs, maintenance, energy and depreciation), the initial analysis was performed using correlation analysis. The correlation coefficients of selected cost items that are key in the production of tomatoes are presented in the Table 6. The results show that seed (r=0.380*), fertilizer (r = 0.341), pesticides (r=0.242), labour (r=0.427) and transportation (r=0.216) costs are significantly correlated with tomatoes yields at the 0.05 level of significance. In contrast, manure (r=0.189) and other (r=112) costs were insignificantly correlated with tomatoes yields.

The table 7 presents the correlation coefficients of selected variables in the data set. The results show that seed (r=0.259*), manure (r=0.218*), fertilizers (r=0.203*), pesticides (r=0.189*) and labour (r=0.374*) were significantly correlated with potatoes yields at the 0.05 level of significance. In contrast, the correlation coefficients for the cost of transportation (r=0.072) and other (r=0.063) costs were not significantly correlated with potatoes yields.

The table 8 presents the correlation coefficients analysis results for selected input factors and yield (output variables) in the production of shallots. The results show that the Pearson's coefficient for fertilizers (0.366), pesticides (0.251) and labour (0.330) were significant at 5% level as evident from corresponding p-value of 0.014, 0.032 and 0.025, respectively. However, the correlation coefficients for the cost of seeds (0.117), manure (0.148), transportation (0.057) and other costs (0.156) were not significantly correlated with shallots yields at 5% level.

DEA was used to measure the relative efficiencies. Table 9 reports the results for the first-stage output increasing DEA efficiency scores across the irrigation systems and farming enterprises; under the assumption of both variable return to scale (VRS) and constant return to scale (CRS).

Comparison of DEA average scores across the irrigation systems

The use of one way ANOVA was adopted in making comparison of DEA average scores across the three irrigation systems. The results are summarized in Table 9.

A closer look at the individual irrigation systems, revealed a significant fluctuations in average scores. The results in Table 9 shows that under the VRS and CRS assumptions, there existed a significant mean difference in DEA scores across the three irrigation systems (P-value = 0.000 and 0.037, respectively). The average DEA scores were highest in drip [0.90 (VRS), 0.20 (CRS)] and sprinkling [0.75(VRS) and 0.17(CRS)] and lowest in Californian [0.64(VRS) and 0.14(CRS)] irrigation systems.

Comparison of DEA average scores across the crop enterprises

The use of one way ANOVA was adopted in making comparison of DEA average scores across the three vegetable crop enterprises. The results are summarized in Table 10. Under the assumption of VRS and CRS, there did not exist significant mean difference in DEA scores across the three enterprises [P-value (VRS) = 0.96 and P-value(CRS) = 0.09]. The average DEA scores under the VRS assumption in the production of tomatoes (0.78), potatoes (0.75) and shallots (0.76) did not differ significantly. Likewise, the average DEA scores under the CRS assumption in the production of tomatoes (0.19), potatoes (0.13) and shallots (0.18) did not differ significantly. Significant levels of inefficiencies ranging between 22% - 25% and 81% - 87% was observed in the three major enterprises under the VRS and CRS, respectively. The average efficiency score across the three crops is about 0.76 and 0.17 under the assumption of VRS and CRS, respectively. This result reveals that there is indeed a presence of inefficiency in the irrigation systems as used in production of the three main crops. This implies that on average farmers in the study area can improve their efficiency or reduce their inefficiencies proportionately, by augmenting their outputs by approximately 24% and 83% without altering the inputs levels, under the assumptions of VRS and CRS, respectively. The results do not only tell us about the level of efficiency, but they also give a strong indication of room for efficiency improvement in the selected irrigation systems.

Conclusion

The irrigation systems as used in production of the three main crops present a level of inefficiency. An average farmer in the study area can improve their efficiency or reduce their inefficiencies proportionately, by augmenting their outputs by approximately 24% without altering the inputs levels. This means that there is room for efficiency improvement in the selected irrigation systems. Drip and sprinkling irrigation systems is relatively more economically efficient as compared with Californian system. The use of manual irrigation system when producing potatoes, shallots and tomatoes is economically undesirable. The use of drip, sprinkling and Californian irrigation systems lead to greater benefits as compared to costs. The excess benefit (compared to costs) is realized more with drip followed by sprinkling and the third being California irrigation system.

Recommendations

More training and capacity building should be channeled to the farmers in the study area with an aim of reducing their levels of inefficiencies in horticultural crop production. There exists greater room for efficiency improvement in drip, sprinkling and Californian irrigation systems.

Farmers should be supported to adopt the use of drip, sprinkling and Californian irrigation systems which lead to greater benefits as compared to costs. The use of drip, sprinkling and California irrigation systems can turn around the profitability status of most farmers in their vegetable production.

Acknowledgements

This material is based upon work supported by the International Center of Agricultural Bio saline (ICBA), the Consultative Group for International Agricultural Research (CGIAR) and the United States Agency for International Development (USAID), as part of the Feed the Future initiative, under the CGIAR Fund, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crisis Mitigation II grant, award number EEM-G-00-04-00013.

References

Alonso, P. and Lewis, G. (2001). Public Service Motivation & Job Performance. Evidence from the federal sector. American Review of Public Administration, 34 (1), 363-380.

Banker, R.D. Charnes, A. and Cooper, W.W.(1984). Some model for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, 30 (9) 1078-1092.

Battese T.J, and Coelli, G.E. (1993). *Frontier production functions when incorporating a model for technical ineficiencies*: Working papers Inn econometrics and applied statistics No 69. Armidale: University of New England, 1993.

Battese, G.E. and Coelli, T.J. (1992). Frontier production functions and technical efficiency on panel data with application to paddy farmers in India. *Journal of Productivity Analysis* 3(1), 153–169

Bettes, G. E. and Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production for panel data. *Empirical Economics*, 20 (1), 325- 332.

Coeli, J.T. (1995). Recent development in frontier modelling and efficiency measurement department of Econometrics university of New England, Armidale NSW. *Australian Journal of Agriculture Economics*, 39(3):219-245.

Coelli, T. J., Prasada Rao, D., and O'Donnel, C. J. (2005). Productivity and Efficiency Measurement Concepts. In T. J. Coelli, D. Prasada Rao, & C. J. O'Donnel, An Introduction to Efficiency and Productivity Analysis (p. 349). Springer.

Cooper, W.W. Seiford, L.M. Zhu, J. Joe Zhu (eds.) (2011). Handbook on Data Envelopment Analysis. Series: *International Series in Operations Research & Management Science*, 2011: Vol. 164.

—. Handbook on Data Envelopment Analysis. Series: *International Series in Operations Research & Management Science*, Vol. 164. 2011.

Drummond, M., Sculpher, M., Torrance, G., O'Brien, B. and Stoddart, G. (2005). Methods for the Economic Evaluation of Health Care Programmes (3 ed.). New York: Oxford University Press. ISBN 9780198529453.

FAO (2009). *Key Water Resources Statistics in Aquastat*: FAO's Global Information System on Water and Agriculture. Rome: FAO.

FAO (2009). *Report of the Independent External Evaluation of the Food and Agriculture Organization of the United Nations (FAO).* Evaluation, Rome: FAO.

FAO (2010). How design, management and policy affect the performance of irrigation. Rome: FAO, n.d.

FAO (2011). *Global action on climate changes in agriculture*: Linkages to food security, market and trade policies in developing countries. Rome: FAO.

FAO. (2010). *Coping with water scarcity: An action framework for agriculture and food security*. Rome: FAO.

FAO. (2012). *FAO water Report on Coping with water scarcity*: An action framework for agriculture and food security. An action framework for agriculture and food Security, Rome: FAO.

FAO. (2012). *How to Design, Management and Policy affects the performance of irrigation*. Rome: FAO.

Guslits, B., & Phartiyal, J. (2010). Women & water in the age of globalization: Protecting our most vital resource. Women & Environments International Magazine (82/83), 12-14.

IPCC(2010). *Climate Change 2010*: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment. New York: Cambridge University Press, 2010.

Kamara, A., Van Koppen, B. and Magingxa, L. (2001). *Economic viability of smallscale irrigation system in context of state withdrawal*: the Arabie Scheme in the Northern Province of South Africa. International Water Management Institute (IWMI), Pretoria, South Africa, 2nd WARSFA/WaterNet Symposium: Integrated Water Resources Management: Theory, Practice, Cases; Cape Town, 30 – 31 October 2001)

Keita, D.M., Bedingar, T., Lubunga, R., Mousseau, L.P.and Matila, M.P.S. (2009). *African Development Fund, Republic of Ghana; Northern Rural Growth Programme*, Osan 2. Appraisal Report, Osan 2.

Kelly, V. (2008). *Agricultural Statistics in Mali*: Institutional Organization and Performance. Background paper for the World Bank (WB) on agricultural. Washington D.C: World Bank.

Kothari, (2004), Research methodology kothari, Sample-size-formula-by-kothari. *The New Age International (P) Ltd. Second revised edition.*

MOA(2013). *Budget and Performance Report*, Mbabane, Swiziland: MOA.

Moffit, F., Macdonald, F. and Robert, A. (2010). The Uses of Tobit Analysi. *The Review of Economics and Statistics*.2(1), 318 - 321.

Mosca, M. and Pastore, F. (2008), Wage effects of recruitment methods: The case of the italian social service sector. IZA Working Paper 3422.

Nyanjom, O. (2011). Devolution in Kenyans' new constitution. Constitution Working Paper Series no. 4. Nairobi: Society for International Development.

Odeck, J. (2009). Statistical precision of DEA and Malmquist indices: A bootstrap application to Norwegian grain producers. Omega, 37(5), 1007-1017.

Plusquellec, H. and Wickham, T. (2009). *Irrigation Design and Management: Experience in Thailand and its General Applicability*. World Bank Technical Paper No 40. Washington: World bank.

Plusquellec, H., Burt, C. and Wolter, H. (2009). *Water Control in Irrigation Systems*: concepts, issues and applications. World Bank Technical Paper No 242. Washington: World Bank.

Plusquellec, H., McPhail, K. and Polti, C. (1990). Review of irrigation system performance with respect to initial objectives. *Irrigation and Drainage Systems Journal*, 1990: Vol. 4.

Reuben M.J. Kadigi, G.T., Alfred, B. and Genet, Z. (2012). Irrigation and water use efficiency in Sub-Saharan Africa. Retrieved from http://www.gdn .int/admin/uploads/editor/files/SSA_4_ResearchPaper_Irrigation_Use.pdfWorld Bank (2000). *An audio-visual training programme on how to improve the operation of canal irrigation systems*. New York: World Bank, 2000.

Reuben, M J., Kadigi, G.T., Bizoza, A., Zinabou, G., (2012). *Irrigation and water use efficiency in Sub-Saharan Africa*, Briefing Paper Number 4 | 2012, GDN Agriculture Policy Series

Sarkar, S. (2013). Prediction of A CRS Frontier Function and A Transformation Function for A CCR DEA Using EMBEDED PCA. *Journal of Data Envelopment Analysis and Decision Science* 2013 (2013) 1-15.

Sithole, N.L.,, Lagat, J.K, and Masuku, M.B. (2014). Factors influencing Farmers Participation in Smallholder Irrigation Schemes: the case of Ntfonjeni Rural Development Area. *journal of Economics and Sustainable Development,* 5(22):159-167.

Todaro, M. P., and Smith. S. C. (2012). *Economic Development policy 11th Edition*. New York University. Developing Countries Economic Policy. Boston: Adison- wesley Publishers USA, 2012.

Triphathi, A., Klami, A., Oresic, M., and Kaski, S. (2011). Matching samples of multiple views. *Data Mining and Knowledge Discovary*, 2011: 20:300-321.

UN (2010). *World Population Momitoring*. Washington D.C: United Nations.

UN (2011). *Food Security Sitation Analysis Report In Africa*. Washington D.C: United Nations.

World Bank (2001). *Rice, E. Paddy Irrigation and Water Management in Southeast Asia*. A World Bank Evaluation Study. OED, Washington: Worldbank, 2001.

World Bank. (2009), Gender dimensions of the extractive industries. Washington, DC: The World Bank.

Yu, J-Y, Zou Y, Kim S T. and Lee T,. (2012). *The Changing Impact of El Nino on US winter Temperatures.* Geophys. Res Lett, 2012: 39 L15702.