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Inefficiency Determinants of Vegetables Producers in Integrated Management Practice of Irrigation Schemes in Limpopo Province of South Africa

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ABSTRACT The study sought to investigate and analyse the inefficiency determinants of tomato and spinach farmers at the integrated management practices of the irrigation schemes in the Limpopo Province. Farm level data were used for the estimation of the parameters of Cobb-Douglas Stochastic Frontier Production Function with a sample size of 80 irrigation farmers. The socio-economic variables included were age, education, gender, family size, land size and ethic group. The results revealed that education level of farmers, age of the farmers and land size were found to be negatively significant toward the technical inefficiency of farmers in the integrated irrigation schemes, which implied that an increase in any of the three variables would reduce the inefficiency and enhance the efficiency. While the family size of the farmer was found to be positively significant, gender and income level of the farmers at different irrigation schemes were found to be insignificant toward the inefficiency of tomatoes and spinach production. Policies designed to educate famers at integrated management practice of the irrigation schemes through proper agricultural extension services could have a great impact in increasing the level of efficiency of tomato and spinach producers at different irrigation schemes.

INTRODUCTION

Spinach has a high nutritional value and is extremely rich in antioxidants, especially when steamed or quickly boiled (DAFF 2012). It is widely produced in South Africa, mostly in Limpopo Province by small-scale farmers. Spinach, along with other leafy vegetables is considered to be rich in iron and vitamins by many consumers. Spinach is sold loose, bunched, packaged fresh in bags, canned or frozen. According to DAFF (2012), spinach contributes about 16 percent of the total vegetable production in South Africa.

According to NDA (2011), tomatoes contribute about 24 percent of the total vegetable production in South Africa. Tomatoes are grown all over the country in summer and in winter in frost-free areas, and their production is concentrated in Limpopo Province, the Mpumalanga Lowveld and Middleveld, the Pongola area of Kwazulu-Natal, the southern parts of the Eastern Cape, and the Western Cape. Growing of tomatoes in tunnels is becoming a popular and important crop production method in South Africa. Tomato is a perennial crop but is grown as an annual plant. South Africa is the second world exporter of the tomato DAFF (2012).

The South African government has established over 160 smallholder irrigation projects in the former Northern Province (Limpopo Province) with the objective of improving the livelihood of rural Black African farmers. Under the previous government, these projects were located in former 'homelands' and were administered in a top-down manner with the objective of local food self-sufficiency. Under the new government of 1994, the provincial authorities have instituted a programme to determine the efficiency and thereby viability of these projects, rehabilitate those that are economically and environmentally viable and hand over the refurbished projects to the community (Van Averbeke et al. 2011).

Various types of management practices/institutional arrangements of the irrigation schemes exist in the whole world. According to the principles delineated in literatures, an attempt was made to categorize irrigation schemes in terms of their management practices. The criteria used are only one way of categorizing most of the existing irrigation schemes, while other such as Tema (2005) used different criteria. The main criteria chosen to classify the irrigation schemes is whether the institutional arrangements of the irrigation scheme covers all the activities which include water management, agricultural extension, applied research, supply of inputs, credit, marketing and basic infrastructure and social service, or a few of these activities, or only those related to water management alone. Within each of these categories, a further distinction is made depending on the degree to which management is controlled by farmers and/or government.

These institutional arrangements/management practices are characterized by an integrated organizational structure where all development activities are undertaken by specialized units which are all connected by a clear line of command and finally responsible to a single person (project manager) or committee. There are several types of integrated management organizations depending on the degree of government and farmers in the management of the scheme (Fanadzo 2010). Where an organization is run by the farmer it usually adopts the structure of a service cooperative. Where government officials are in full control of the organization, there are two possibilities depending on the size of the production units: State farm (large production units) and Irrigation settlement projects (Small Production Units).

Increased output from irrigated agriculture may lead to improved yields, reduced crop loss, improved cropping intensity and increased cultivated area (Namara et al. 2010). Accordingly, reliable access to water enhances the use of complementary inputs such as high-yielding cultivars and agrochemicals which also increase output levels and thereby improve farm income and reduce poverty (Smith 2004). Due to the land scarcity, it is difficult to increase tomato and spinach production by increasing the land size under cultivation. However, there is an opportunity to increase production of tomato and spinach by improving the existing production technology.

MATERIAL AND METHODS

Data Source and Sampling Technique

The field survey was conducted covering the five district of Limpopo Province in the year 2011. A total of 200 sample farmers at different management practices of the irrigation schemes were selected from a pool of farmers using purposive and cluster sampling techniques. The farmers from different irrigation schemes were sampled using purposive sampling technique and grouped according to their types of management practices of their irrigation schemes, wherein only 80 irrigation farmers under the integrated management practices were purposively considered. Face- to- face interview was used for data collection. The collected data were scrutinized and validated carefully to achieve the meaningful interpretation (that is, data verification and grouping based on individual vegetable).

Model Specification

Stochastic frontier production function model of Cobb-Douglas type was employed to analyse the technical efficiency of tomato and spinach irrigation farmers.

$$\text{In } Y = b_{01} \text{ In } X_{1i} + b_{2i} \text{ In } X_{2i} + b_{3i} \text{ In } X_{3i} + b_{41} \text{ In } X_{4i} + b_5 \text{ In } X_{5i} + b_{6i} \text{ In } X_{6i} + v_i - u_i \quad (1)$$

where the subscript, i indicates the i-th farmer in the sample (i= 1, 2, 3, n), ln representing the natural logarithm (that is, logarithm to base e)

Output (Y) is the total quantities of tomato or spinach harvested in that year and are measured in kg per hectare.

Land (X_1) is the area of the farm(s) devoted to the production of tomato or spinach. It is measured in hectares.

Labour (X_2) is the total of tomato or spinach service rendered. It is expressed in adult equivalent days per hectare and is the sum of family labour and hired labour. Male and female labour is counted equally.

Capital (X_3) Coudere and Marijse's (1991) argument was used. There was not much variation in the types of equipment farmers possesses. All were assumed to use tractors. To represent capital, a cost of tractor service charged per hectare for irrigation schemes was used.

Fertilizer (X_4) includes both basal and top dressing fertilizers. Although some farmers use animal manure, this has been also included as long as he/she knows how many kilograms have been used (It is measured in kilograms).

Seed (X_5) both certified and home produced (recycled seeds) is considered and is measured in kilograms.

Cost (X_6) pesticides, irrigation water, chemicals costs are included and are measured in Rand.

The v_i is random errors associated with measurement errors in the yields of tomato or spinach reported or the combined effects of input variables not included in the production function, where v_{is} are assumed to be independent and were obtained by truncation (at zero) of the normal distribution with mean, μ_1 and variance, σ^2 such that

$$\mu = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} \quad (2)$$

where- coefficients are unknown parameters to be estimated, together with variance parameters, which are expressed in terms of land size (Z), family size

(Z_{2i}), education (Z_{3i}), age (Z_{4i}), gender (Z_{5i}) and income level (Z_{6i}) as defined below.

Land size = the total number of hectares held by the farmer.

Family size = total number of household members.

Education = the number of years of schooling completed by the household head (who in this case been the farmer).

Age = the age of the household head in years.

Gender = the gender of the household head.

Income level = the level of household income

The computer program Frontier 4.1 that was designed by Battese and Coelli (1995) was used to analyse the data. The maximum likelihood estimates of the parameters of the frontier model were estimated, such that the variance parameters were expressed in terms of the parameterisation:

$$\sigma^1_s = \sigma^2_v + \sigma^2 \text{ and } y = \frac{\sigma^2}{\sigma^2_s}$$

RESULTS AND DISCUSSION

Land, capital, labour and management are always given as the main factors of production in agriculture. The management input includes both the physical properties and personal qualities possessed by the farmers. According to Bembridge (1997), this sub-divides the human resource input into two distinctly different and mutually exclusive inputs, that is, labour and decision making and management.The constraints and problems that have been discussed above are some of the main causes slowing down the progress of smallholder farmers towards successful farming, mainly determined by how the initiative is implemented. However, there are other factors that have been found in other studies, for example, Dlova et al. (2004). Table 1 and Table 2 show the results from the empirical model.

Inefficiency Determinants

Table 1, the coefficient of *age* of farmers in the integrated management practices of irrigation schemes for both tomato and spinach production was found to be -0.01 and -0.22 respectively. It was revealed that the *age* has a negative significant effect upon the technical inefficiency in the both production of tomato and spinach. This implies that as the *age* of the farmers at different irrigation schemes increases, the technical inefficiency of both tomato and spinach decline. The coefficient for years of schooling was revealed to be negatively significant (that is, -0.03 and - 0.07 for tomato and spinach respectively) in the integrated water manage-

Table 1: Estimated parameters for technical efficiency of vegetables production of the irrigation schemes

Variable	*Parameter*	*Estimated coefficients*	
Integrated management practices of the irrigation schemes		*Tomato*	*Spinach*
Stochastic Frontier Constant	β_0	0.99*** (0.14) [6.99]	0.75** (0.16) [4.71]
Land	β_1	-0.32* (0.13) [2.37]	0.92*** (0.14) [6.72]
Seed	β_2	(0.14) [6.12]	(0.15) [3.75]
Fertiliser	β_3	0.57** (0.15) [3.77]	0.44* (0.19) [2.33]
Labour	β_4	-0.03 (0.03) [1.05]	-0.38 (0.21) [1.82]
Capital	β_5	-0.01 (0.01) [0.89]	0.33 (0.16) [2.12]
Pesticides	β_6	-0.02 (0.03) [0.77]	-0.07 (0.09) [0.81]
Sum of Coefficients	$\Sigma\beta_5$	1.02	1.80
Adjusted R^2		0.86	0.84

*Significant at 10% **Significant at 05%
***Significant at 1%
Figures in parentheses ( ) are the standard error of estimates whereas figures in brackets [ ] represent t ratios of coefficients.

ment practices of the irrigation schemes. These results indicates that the more educated tomato and spinach producers are, the more will they likely become efficient as compared to their less educated counterparts, perhaps as a result of their better access to information and good farm planning. Hassan (2004) also found a significant rapport between *education level* and the adoption of improved production technology.

Table 2, show that the estimated coefficient for the *family size* was revealed to be positively significant (that is, 0.79 and 0.92 for tomato and spinach respectively) in the integrated water management practices of the irrigation schemes for the selected agricultural produce (that is, tomato and spinach) at 99 percent. The positive sign indicates that the larger the *family size*, the greater is the technical inefficiency for both tomato and spinach producers at different irrigation schemes. The estimated coefficient of *land size* was found to have negative significant towards farmers' technical inefficiency in the integrated water management practices of irrigation schemes for the production of tomato at 95 percent level whereas it was found to be positively significant towards technical efficiency in the production of spinach at 99 percent. The different between the two in terms of the direction of significance (that is, positive and negative significant) might be attributed to the fact that tomato production need more land as compared to spinach production.

Table 2: Estimated parameters for inefficiency determinants in vegetables production of the irrigation schemes

Variable	*Parameter*	*Estimated coefficients*	
Integrated management practices of the irrigation schemes		*Tomato*	*Spinach*
Stochastic Frontier	δ_0	0.52* (0.16) [3.21]	0.42* (0.20) [2.11]
Land Size	δ_1	-0.22* (0.07) [3.33]	0.92* (0.14) [6.72]
Family Size	δ_2	0.79*** (0.15) [5.13]	0.91*** (0.15) [6.12]
Education	δ_3	-0.13* (0.06) [2.13]	-0.07** (0.02) [4.55]
Age	δ_4	-0.01** (0.01) [3.32]	-0.22** (0.07) [3.36]
Income Level	δ_5	-0.04 (0.04) [1.07]	-0.03 (0.03) [1.05]
Gender	δ_6	0.22 (0.18) [1.20]	0.21 (0.20) [1.07]
Variance Parameter	σ^2	0.01** (4.22)	0.02*** (5.61)
	γ	0.99*** (6.88)	0.99*** (6.89)
Log (Likelihood) Function		-43.82	71.22
Average Technical Efficiency		0.78	0.80

*Significant at 10% **Significant at 05%
***Significant at 1%
Figures in parentheses ( ) are the standard error of estimates whereas figures in brackets [ ] represent t ratios of coefficients.

The estimated coefficient of *household income* level was found to be negatively insignificant towards farmers' technical inefficiency the integrated water management practices for the production of both tomato and spinach. The estimated coefficient of the *gender* of the farmer was found to be positively insignificant towards farmer's technical inefficiency in the integrated water management practices for the production of both tomato and spinach, implying that gender is inelastic towards inefficiency of vegetables producers; perhaps this is as a result of the female dominants in various irrigation schemes. Table 3 shows the hypothesis were tested.

The critical values are at 5 percent level of significance and the critical values were obtained from table of Kodde and Palm (1986). The null hypotheses which include the restrictions that are zero not have a chi-square distribution because the restriction defines a point on the boundary of parameter space (Baten and Palm 2012).The test statistics was assumed to be asymptotically distributed as mixture of chi-square distribution with degree of freedom equal to the number of restrictions involved. The restrictions imposed by the null hypothesis are rejected when exceeds the critical value (Taymaz and Saatci 1997; Baten and Blum 2011).

For the yield specification model, the null hypothesis in the integrated management practice of the irrigation schemes for both tomato and spinach production, H_0: γ=0 which specifies that there is no technical inefficiency effects in the model? Since the hypothesis was

Table 3: Likelihood test ratio of hypothesis of the stochastic frontier production for the yield model of tomato and spinach

Integrated Water Management Practice				
Null hypothesis	*Log-likelihood function*	*Test statistics*$^{\lambda}$	*Critical values*	*Decision*
H_0: γ=0				
Tomato	68.43	96.35	9.913	Reject H_0
Spinach	71.22	90.33	9.913	Reject H_0

Source: Regression results

rejected in both tomato and spinach production in the integrated management practices of the irrigation schemes so the study can conclude that there are technical inefficiency effects in the model.

CONCLUDING REMARKS

The MLE of the parameters of the stochastic frontier model of both tomato and spinach showed that estimates of the parameters for the frontier production function, inefficiency model and the variance parameters of the model in the integrated management practice of the irrigation schemes (Table 2). The parameter sigma squared, (σ^2) were found to be 0.01 and 0.02 for tomato and spinach respectively in the integrated water management practice of the irrigation schemes. The parameter sigmas squared were found to be significant at 95 percent and 99 percent for tomato and spinach respectively in the integrated management practices of the irrigation schemes. This indicated a good fit and correctness of the distributional form assumed for the composite error term. Gamma (γ) indicated that systematic influence, which was un-explained by the production function, was the dominant source of random error. The gamma estimates (0.99) in the integrated water management practice of the irrigation scheme show the amount of variation resulting from the TEs of the both tomato and spinach farmers. This implied that more than 95 percent of the variations in both tomato and spinach productions were due to differences in technical efficiencies. The average mean technical efficiency of both tomato and spinach were found to be 0.78 and 0.80 for the production of tomato and spinach respectively. Based on the analysis above, we can concluded that there are no major differences with regard to the inefficiency determinants for the production of tomato and spinach in the integrated management practices of the irrigation schemes.

RECOMMENDATIONS

It is evident from the results that tomato and spinach production in the integrated management practices of the irrigation schemes could be increased substantially with current technology and available resources, if technical and allocative inefficiencies are overcome somehow. Education level of the farmer was found to be significant in both tomato and spinach production. Policies designed to educate famers at integrated management practice of the irrigation schemes through proper agricultural extension services could have a great impact in reducing the level of inefficiencies of tomato and spinach producers at different irrigation schemes. The Department of Agriculture should allocate more funds to strengthening the extension directorate and expanding the delivery of extension services to farmers at different irrigation schemes.

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