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ECONOMIC EFFICIENCY OF SWEET-POTATO SMALLHOLDER FARMERS AT VUVULANE IRRIGATED FARMS-LUBOMBO REGION OF ESWATINI

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Abstract

Among the irrigation schemes established to benefit smallholder farmers in Eswatini includes Vuvulane irrigated farms (VIF). Since introduction of new crops other than sugarcane production, there has not been any study to establish the economic performance of the smallholder sweet-potatoes farmers in terms of profitability efficiency. Therefore, this study was

aimed at examining the economic efficiency of smallholder sweet-potato farmers at Vuvulane irrigated farms (VIF) and determines the factors influencing the economic efficiency. The study used primary data collected from 60 farmers cultivating at Vuvulane irrigated farms (VIF). The study employed Cobb Douglas stochastic profit function to estimate economic efficiency scores for sweetpotato farmers, and an OLS model was used to determine the factors affecting economic efficiency. The sweet-potato farmers interviewed can be characterised as aged 44 averagely, with farming experience of 6 years, earning average farm income of 51165, and off farm income of 11468. The average land size allocated for sweet-potato production on the irrigation scheme was 0.3 hectares per farmer. Further, the farmers sample cultivating on the irrigation schemes can be described as mostly males (70%), not married (52), attained formal education (95), and not formally employed (87%). The findings of the study indicate that the sweet-potato farmers at VIF-scheme were economically efficient at 64%, meaning that they have 36% room of improving to attain maximum efficiency. Determinants of sweet-potato farmers' economic efficiency were gender and education. The study concludes that male farmers who attained some formal education are more economically efficient. Therefore the study recommends that for improved profitability and economic efficiency of sweet potato production, all stakeholders including the government, private sector, NGOs, and CBOs among other they should develop programs and projects aimed at increased irrigated land access to farmers and reduce cost of land preparation, and increase the number of males involved in sweet production and adult education programs to close the gap of limited access to formal education, respectively.

Keywords: Economic efficiency, Stochastic Profit Frontier Function, Sweet-potato, Eswatini

INTRODUCTION

Smallholder agricultural sector in developing countries plays a vital role of improved food security and all-purpose livelihood of especially rural residents in developing and low middle income countries worldwide. Among the root crops of main importance in reducing food insecurity includes sweet-potato (*Ipomoea batatas (L.) Lam*) (Abrham *et al.,* 2021). According to Abrham *et al.* (2021), sweet-potato is ranked as the third important root crop globally, after cassava and Irish potato. Globally, about 106 million tons of Sweet-potato are produced on 8 million hectares (2016). Sweet-potato is one of the mostly grown food crops in Eswatini, ranked second after maize (Ministry of Agriculture-Eswatini (MoA), 2020). Eswatini sweet potato production per capita was reported as 2.16kg in 2018 and regarded low compared to other

Southern African countries like Malawi and Mozambique who recorded 295.8 kgs per capita and 20.5 kgs per capita, respectively *(*FAOSTAT-nd*)*.

The climate in Eswatini is advantageous for Sweet-potato production and it is grown-up in the all four regions of the country, namely Shiselweni, Mazini, Hhohho and Lubombo. Most sweet-potato production is rain-fed in all regions (MoA, 2019; Tfwala *et al.,* 2020). Since sweet-potato is ranked the second most grown food crop, the Government of the Kingdom Eswatini has selected Sweetpotato as one of the food crops that can be used to improve food security in the country. For a successful increased production of root and tuber crops rest on the governments strategies aimed at addressing challenges of increasing climate change events like erratic rainfall, limited access to planting materials/seed and poor extension services, among others ((MoA, 2016). Distribution of irrigated land to smallholder sweet-potato farmers was viewed among strategies for increased production, profitability and efficiency, and this comprises the Vuvulane Irrigation Farm.

This study aimed at estimating the government's contribution towards improved sweet potato production and farmer's earned incomes by estimating the farmers' economic efficiency employing the Cobb-Douglas Stochastic Profit Function (CDSPF). The stochastic profit Function approach combines the concepts of TE and AE in the profit relationship. So, the profit function was chosen over the production function because the production function requires that TE and AE be regressed separately in order to estimate EE, while the profit function just analyses EE directly. In Dziwornu and Sarpong (2014) research a modified stochastic Cobb-Douglas profit frontier model with inefficiency effect component behaviour was used for a study (Dziwornu and Sarpong, 2014). Several authors that have attested the efficacy of the stochastic profit function as a measurement of farmers' performance they include Masuku et al. (2014) who estimated the economic efficiency of smallholder dairy farmers in Eswatini: An application of the profit function; Keit et al. (2020), they conducted a study titled "applying cobb–Douglas stochastic frontier Profit function: a case study of hoaloc-mango in the Mekong delta in Vietnam; Sanusi and Singh (2015) carried out a study titled, Application of stochastic frontier function in measuring profit efficiency of small-scale maize farmers in Niger State, Nigeria; Mulie (2014) conducted a study on the Determinants of Profit Efficiency of Coffee Producing and marketing Cooperatives (The Case Study of Sidama Coffee Farmers' Union); Mwita (2013) employed the profit efficiency approach to estimate efficiency among sweet yellow passion fruit farmers in Mbeere south, Embu County; and Kaka et al. (2016) conducted a study titled "profit efficiency among paddy farmers: a cobb-Douglas stochastic frontier production function analysis.

METHODOLOGY

Research Design and Sampling

The present study was based on both qualitatively and quantitatively designed to clearly establish and analyze Economic/profit efficiency of farmers producing Sweet-potato at Vuvulane Irrigation Farm smallholder's Scheme in the Lubombo region of Eswatini. The irrigation scheme was established in 1962, during the colonial regime. It covers 1,203 ha of TDL. It was established majorly (70%) to produce sugarcane and supply to the Mhlume sugar mill (Alan and Ogg, 2017). Although the soils are shallow they can easily allow water penetrating through it and regarded suitable for irrigated crop production. The extension worker provided a list of 190 small-scale Sweet-potato farmers cultivating on the Vuvulane Irrigation scheme and 60 farmers were sampled, and questionnaires were administered to completion. Technically the study employed purposive sampling.

Data analytical model

Enterprise economic efficiency was analysed using the linear Cobb-Douglas production function which was in the form of a profit function and Stochastic Frontier Analysis. Determinants of enterprise economic efficiency were analysed using OLS. The study assumed that seasonal (6 months) profits obtained by each farmer was dependent on land preparation costs, seed costs, fertiliser costs, agrochemicals costs, labour costs, transport costs, as well as land area size (hectares) cultivated. However, the researchers could only access data related to only revenues, land preparation costs, seed costs, and land area size. Given the accessed data, the general model used for estimating the stochastic profit function can be expressed as:

$\pi = f(X_1, X_2, X_3)$……(1)

The following table show the description of the variables.

Table 1: The Cobb Douglas Stochastic Production Frontier variables

	Variable	Description	Unit of measurement
π	Gm	Gross margins (6 months)	Emalangeni
X_1	LandPrep	Land preparation costs	Emalangeni
X_2	Seeds	Seed costs	Emalangeni
X_3	AreaCultivated	Output per hectare	hectares

Generalised empirical form of the model:

Π = *f (Land preparation costs* X_1, X_2 *seed costs,* X_3 *area cultivate*……(2)

Normalised Cobb-Douglas stochastic profit function

$\Pi^* = \beta_0 X^*_1 \beta 1\, X^*_2 \beta 2\, X^*_3 \beta 3\, e^{Vi-Ui}$…… (3)

The above function was linearized by taking the natural logs of both the dependent variable and the independent variables. The log form of the function then became:

Linearized Cobb Douglas stochastic profit function

$\ln\pi^* = \beta_0 + \beta_1 \ln X_1^* + \beta_2 \ln X_2^* + \beta_3 \ln X_3^* + (Vi - Ui)$……..(4)

Where:

$\ln\pi$	:	Natural log of the gross margin normalised by output unit price.
$\ln X_1^*$	:	Natural log of land preparation costs normalised by output unit price
$\ln X_2^*$	:	Natural log of seeds costs normalised by output unit price
$\ln X_3$	:	Natural log of area cultivated
$\beta_0 - \beta_3$	:	Unknown parameters to be estimated
$(V_i - U_i)$	:	Random error term

- V is a 2 sided normally distributed random error that captures stochastic effects that the enterprise cannot control e.g., drought, natural disasters etc. It also captures measurement errors and statistical noise.
- U is a 1-sided efficiency component that captures economic efficiency. It measures the shortfall in profit from its maximum point given by the stochastic frontier. Assumed that U has an exponential distribution.
- V and U are assumed to be independent of each other,

Estimation of factors affecting economic efficiency of Sweet-potato farmers

The OLS model was chosen for further analysis.

$Yi = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_{8+} e$……(5)

Where:

Yi	:	EE score (Level of EE)
X_1	:	Age (years)
X_2	:	Gender (0=male, 1=female)
X_3	:	Education level (0=no formal education, 1=attended formal education)
X_4	:	Employment status (0=not employed, 1= formally employed)
X_5	:	Market type (0=non-contract markets, 1=contract markets)
X_6	:	Sources of labour (0=non-hired labour, 1=hired labour)
X_7	:	Off-farm income (E)
X_8	:	Crop cycle length (months)
β_0	:	Intercept
$\beta_1 - \beta_8$	:	Coefficients
e	:	Error term

RESULTS AND DISCUSSION

The results presented in Table 2 indicate that sweet-potato farmers on average were 44years old. This implies that the most farmers were the youthful age bracket and thus energetic and productive for increased productivity and efficiency. Age is sometimes used to symbolise farming experience the older the farmer the more experience, however, researches carried by other researchers have mixed results. Mulie (2014) when analysing the Determinants of Profit Efficiency of Coffee Producing and Marketing Cooperatives found that when farmers get older and older, inefficiency gets high. This is mainly because older age farmers are fading up with long years of farming and are reluctant to adopt and introduce new technologies and are inelastic to changes in farming systems. Mwita (2013) found out that the age of farmers had a negative coefficient indicating that there was a negative relationship between age of the farmer and profit inefficiency. This implies that older farmers were able to decrease their inefficiency thus increase their efficiency more than the young farmers. This is in arrangement with theory as older gain from experience and is able to improve their productivity.

Table 2 Socio-economic characteristics of respondents (Quantitative variables)

	Sweet potatoes	
Variable	**Mean**	**Std. Dev.**
Age	44	11
Crop cycle duration	4	0
Experience in enterprise	6	3
Annual farm income	51165	19187
Annual off-farm income	11468	21924
Total income	62623	19325
Area harvested	0.3	0.3

The crop cycle duration variable was a numeric variable showing the length of a crop cycle expressed in months. In Eswatini, sweet-potato enterprises have an average crop cycle length of 4 months. The sweet-potato farmers also had a farming experience of this particular enterprise of 6 years. Farming experience is thought to be important in improving efficiency. A study carried out by Mwita (2013) assessed profit efficiency among sweet yellow passion fruit farmers in Mbeere south, embu county and it was found out that farming experience had a negative influence on inefficiency meaning that farm experience positively influences farm efficiency.

According to the information gathered from the farmers and presented in Table 2, Sweet potato farmers cultivating at the VIF irrigation scheme on average they earn E51165 farm income and E11468 off-farm income respectively. In total, the farmers were earning about total annual income of E62623 at the time the research was carried out. All farmers cultivating on the VIF-irrigation scheme were allocated only 0.3ha of land. Farmers who choose to grow sweet potatoes are normally those who has other income generating activities to do e.g., causal employment, selling in the markets, among other employment options. Such farmers do not have enough time to work in the farm hence they choose to grow sweet potatoes. Access to extra off-farm income is important in farming because such incomes contribute to purchasing of inputs and cushion farmers during the long gestation period before harvesting. Further this provides enough time for the farmers to store their produce and gain from better prices towards off-season/scarcity of the commodity. This is thought to be an incentive enough to influence farmers' productivity and efficiency. Mulie (2014) when analysing the Determinants of Profit Efficiency of Coffee Producing and Marketing Cooperatives in Ethiopia found out that off-farm income reduces inefficiency. A coefficient of -0.003 significant at 1% was found. The results meant that an increase in off-farm income increases efficiency. Mwita (2013) found that Access to off-farm (non-sweet yellow passion) income had a positive relationship to profit efficiency. The variable had an increasing effect on the farmer's profit efficiency thereby reducing their profit inefficiency levels.

Table 3 presents categorical social-economic variables of the respondents. Most farms at VIF are being used by the 2nd generation and amongst the generation 70% of those that work in the farms are males who work in the farm and provide rent or dividends to their female siblings. The migration of females to communities away from VIF due to marriage also contributes to the domination of male farmers in the farms. Even when the females had a passion for farming the land, when they get married, they are forced to abandon it and migrate to their matrimonial communities. Sossou et al. (2014) mentioned that a shift of the household head gender from man to woman status diminished farms efficiency. He attributed it to women's limited access to production inputs like land, capital, and credit. Chimai (2011) established that gender of the household head was significant in explaining field crop production efficiency. Male headed households had higher levels of efficiency than female headed households. Mwita (2013) found out there were more profit efficient male farmers than female farmers. It can therefore be deduced that male farmers are able to reduce inefficiency and increase their profit efficiency better than their female counterparts.

Table 3: Socio-economic characteristics of respondents (Qualitative Variables)

Variable	Frequency	%
Gender		
Male	42	70
Female	18	30
Total	**60**	**100**
Martials status		
Single	31	52
Married	29	48
Total	**60**	**100**
Education Level		
No formal education	3	5
Formal education	57	95
Total	**60**	**100**
Employment status		
Formally Employed	8	13
Not employed	52	87
Total	**60**	**100**

Kaka et al. (2016) when analyzing the profit of efficiency among paddy farmers found that marital status has no significant impact on profit efficiency. About 52% of the farmers were single and 48% married. There are more single farmers than married farmers growing sweet-potato at VIF though the difference is not significant. This shows that land allocation at VIF is not based on the marital status of a person. Young people who are not married are able to access land and produce sweet-potato. In some communities in Eswatini people who are single are still not allowed to acquire land. At VIF, Single people are free to inherit land or lease land for agricultural production.

Most extension service materials are presented in English and also workshops are conducted in English as an official language with a mixer of Swazi language. Thus, farmers need to have attained some form education to be able to understand and interpret the material for improved productivity and efficiency. This confirmed by the research which was carried out by Mwita (2013) who found out that the farmers' level of education which was measured in the number of years spent in school had a negatively significant coefficient implying that more number of years in school decreased profit inefficiency, and thus increasing profit efficiency of the farmers. Results presented in Table 3 indicate that most sweet-potato farmers (95%) at VIF attained some form Education. The high percentage of farmers who acquired some formal

education can be explained by improved access to this service due to the educational infrastructure that was set up in Vuvulane by the government of Eswatini. There is a primary and high school that was built in the middle of VIF for the benefit of the community using the farm. VIF is also located between 2 estates (Tongaat Hullet and Mhlume sugar estate) who all has high quality educational infrastructure which VIF members can access as well. This makes VIF quite an educated community which is good for agricultural related service delivery.

Amongst the farmers interviewed, the results showed that 87% were unemployed and only 13% were formally employed. Employed farmers do not have enough time to work on the fields as they spend most of their time at work. Employed farmers can mitigate this risk by hiring extra labour to work in their fields whist they are away. Employed farmers are able to buy any farm input required as they get a salary every month which is an advantage to them over their unemployed counterparts. Unemployed farmers have all the time to work in the farm which improves productivity however, they often lack required farm inputs due to lack of financial resources. Unemployed farmers rely on formal and informal loans for the upkeep of their farm. This is the biggest disadvantage unemployed farmers face. This may call for more business innovations & entrepreneurial capacity building and financing the farming activities, transformed into more commercialization, and thus reducing on unemployment.

Efficiency estimates for sweet- potato enterprise

Only 3 variables were examined under sweet potato production and they are cost of land preparation, cost of seeds (vines) and area under production. Farmers at VIF do not apply fertilizers or chemicals when producing sweet potatoes. Fertilisers negatively affects the taste of the tubers hence they avoid it. The estimation of the Cobb-Douglas Stochastic Profit Frontier Function generated the results for the maximum likelihood estimates (MLE) presented in the table below. Cost of land preparation was significant at 5% with a positive sign. Area cultivated was significant at 1% with a positive sign. A 1% increase in land preparation costs and area cultivated would increase biannual profit by 25% and 123%, respectively.

Table 4: Stochastic profitability frontier estimates for sweet-potato

Independent Variables	Dependent variable = Gross margin (E)			
	Coef.	Std. Err.	z	P>z
Ln Cost of land preparation (E)	0.251**	0.010	2.510	0.012
Ln Cost of seeds (E)	-0.303	0.195	-1.560	0.119
Ln Area cultivated (hectares)	1.231***	0.233	5.290	0.000
_cons	6.154	0.530	11.620	0.000

/lnsig2v	-3.737	0.732	-5.110	0.000
/lnsig2u	-1.189	0.345	-3.440	0.001
sigma_v	0.154	0.056		
sigma_u	0.552	0.095		
sigma2	0.328	0.098		
lambda	3.574	0.132		
Number of obs		=	60.000	
Wald chi2(3)		=	80.850	
Prob > chi2		=	0.000	
Log likelihood		=	-38.561	
Likelihood-ratio test of sigma_u=0: chibar2(01) = 7.28 Prob>=chibar2 = 0.003				

Table 4…

Note ** = significant at 5% level; *** = significant at 1%

Most sweet-potato farmers (30%) were economically efficient between 80% and 89%, and only 28% of the sweet-potato farmers were operating below 50% economic efficiency. Thus, 72% of the farmers were operating above 50% economic efficiency although they have room to improve to attain 100% economic efficiency. The mean EE scores of the sweet potato farmers were 3th on the rank with mean EE score of 64% meaning that on average farmers need to improve their economic efficiency by 36% to attain 100% efficiency.

Table 5: Economic efficiency distribution of all sampled enterprises

Range of EE-Scores (%)	**Frequency**	**%**
<10	1	2
10-19	1	2
20-29	5	8
30-39	2	3
40-49	8	13
50-59	8	13
60-69	8	13
70-79	5	8
80-89	18	30
≥90	4	7
Average EE		64
Minimum EE		27
Maximum EE		74

Factors affecting efficiency for sweet-potato enterprise

Amongst the variables analyzed amongst sweet potato farmers; crop cycle duration, education level and business training were found to be significant.

Table 6: Factors affecting economic efficiency of sweet potato farmers

Explanatory variables	Dependent variables = Economic efficiency scores			
	Coef.	**Std. Err.**	**t**	**P>t**
Market type (0=walk-ins, 1=contracts)	0.226	0.143	1.580	0.120
Labour source *(1=hired, 0=non-hired)*	-0.013	0.037	-0.360	0.718
Gender *(0=Male, 1=Female)*	-0.180**	0.105	-1.710	0.094
Age *(Years)*	0.006	0.005	1.110	0.273
Employment status *(1=Employed,0=unemployed)*	0.210	0.130	1.610	0.113
Education level *(1=formal,0=otherwise)*	0.099**	0.055	1.780	0.081
Crop cycle duration *(Months)*	-0.094	0.136	-0.690	0.491
Off-farm income *(E)*	-4.74E-06	4.09E-06	-1.160	0.252
_cons	-0.016	0.657	-0.020	0.981
Number of obs	=	57.000		
F (8, 48)	=	2.000		
Prob > F	=	0.067		
R-squared	=	0.250		
Adj R-squared	=	0.125		
Root MSE	=	0.309		

Note: ** = significant at 5% level;

Education level- The variable was a binary variable with 0 representing those who never attended formal education and 1 representing those who attended formal education. The variable was significant at 5% level of significance with a positive sign. This means that attending formal education increased economic efficiency by 8% at VIF amongst sweet potato farmers. These findings are similar to the findings in the factors affecting EE on green mealies enterprises. Sweet potatoes are known to be the very simplest crop to grow. Many farmers believe that preparing the soil and planting the vines are the only production practices. It has come out that yields can be significantly improved by proper vine selection, proper treatment of soils, nutrient supplementation, pest and disease control and well as weed control. Farmers with formal education tend to make better farm decisions with regards to the above stated production practices compared to their counterparts which improve their efficiency. These results agree

with the findings of Peprah (2010), which found that well educated farmers are able to produce vegetables efficiently. Such people are able to apply fertilizers and other chemicals by following the instructions on the labels. Farmers whose level of education is low become technically inefficient in vegetable production.

Gender- The variable was binary with 0 representing males and 1 representing females. The variable was significant at 5% with a negative sign. This means that being female farmer at VIF resulted to a 9% decrease in the economic efficiency of sweet potato farmers. Sweet potato farming is labour intensive especially during harvesting. Female farmers have more responsibilities than their male counterparts outside farm. This results to females failing to cope with the labour requirements especially during harvesting. This results to the tubers staying for a long time in the ground hence increasing the crop cycle length thus reducing economic efficiency. As sweet potato tubers stay long in the ground, they also lose some quality in terms of the desired tuber size. Delayed harvesting can result to the rainy season negatively affecting the taste of the tubers. It is important that when tubers reach the desired maturity and quality, they be taken off the field as quick as possible which male farmers are able to do compare to their female counterparts.

CONCLUSIONS AND RECOMMENDATIONS

The sweet-potato farmers interviewed can be characterised as aged 44 averagely, with farming experience of 6 years, earning average farm income of 51165, and off farm income of 11468. The average land size allocated for sweet-potato production on the irrigation scheme was 0.3 hectares per farmer. Further, the farmers sample cultivating on the irrigation schemes can be described as mostly males (70%), not married (52), attained formal education (95), and not formally employed (87%). The findings of the study indicate that the sweet-potato farmers at VIF-scheme were economically efficient at 64%, meaning that they have 36% room of improving to attain maximum efficiency. Determinants of sweet-potato farmers' economic efficiency were gender and education. The study concludes that male farmers who attained some formal education are more economically efficient.

Therefore the study recommends that for improved profitability and economic efficiency of sweet potato production all stakeholders including the farmers, government, private sector, NGOs, and CBOs, among other, they should develop programs and projects aimed at:

1) Attracting and allocating more land under irrigation to women and encouraged to them to produce sweet-potato.
2) Ensure sustainability the male youth participation in sweet-potato production on the VIF scheme

3) Expansion of the irrigation scheme which in turn will increase the hectares from 0.3 to at least 2 hectares to meet the demand of the population and improve on the livelihoods and food security of the farmers.
4) Reducing the cost of land preparation through subsidising the Rural Development Area tractor hire schemes services.

LIMITATIONS OF THE CURRENT STUDY

Sweet potato is grown-up in all four administrative regions of Eswatini (Swaziland), namely Shiselweni, Mazini, Hhohho and Lubombo. In addition to being the population targeted study area, due to the researchers' constraints of funds and time, this study was only carried out at Vuvulane Irrigation Farm smallholder's scheme in the Lubombo region among 60 out of 190 sweet potato farmers. There are several methods of estimating economic efficiency but this study selected the stochastic profit function because of its ability to capture inefficiencies related to quantity of inputs and prices of the inputs and output avoiding the farm to recommend different "best practices"; further, it is more flexible with the ability to estimate directly efficiency of a specific farm; and the economic efficiencies estimated when employing the stochastic profit function are generated simultaneously without going through the process of separately estimating of technical, allocative and scale efficiency (Dziwornu and Sarpong, 2014). However, the findings of this study can be referred to by other researchers and policy makers not only in Eswatini but globally especially for smallholder farmers cultivating on irrigation schemes.

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