Research Article

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Technical Efficiency of African Indigenous Vegetable Production in Vhembe District of Limpopo Province, South Africa

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Abstract: African indigenous vegetables (AIVs) have long been known in South African rural communities as essential food that is being consumed with starchy staples, and their consumption has increased over the past few decades. There is now a growing interest and awareness of AIVs due to their nutritional benefits and outstanding potential to generate farm incomes. However, several factors are militating against their production along the supply chains of value addition. This study analysed the technical efficiency of AIVs production in Vhembe district of Limpopo province. The data were collected from 114 AIVs farmers through a multi-stage sampling technique. Data analysis was carried out using Stochastic Frontier model via the Cobb-Douglas production function. The results revealed that the average age and years of farming experiences of the farmers were 59.6 and 30.9 years respectively. About 84% of the farmers lacked access to formal credit, while 92% had access to extension services. Elasticity values of land area cultivated, fertiliser, seeds, labour and tractor days in relation to AIV production were 0.4441, 0.1749, 0.1311, 0.2663 and 0.2360 respectively. Furthermore, the results revealed that average technical efficiency in the production of indigenous vegetables was 0.79%. The variables that significantly influenced technical inefficiency were years of schooling, extension services, gender and access to the irrigation system. In conclusion, production of AIV exhibits decreasing returns to scale. However, promotion of AIV production and efficiency requires consideration of gender issues in accessing resources, educational attainments of farmers, access to irrigation services and proper reorientation of the com-

ponents of agricultural extension services delivery in order to benefit AIV farmers.

Keywords: Indigenous Vegetable; Efficiency; Limpopo; South Africa

1 Introduction

In South Africa, vegetable production constitutes a significant source of food and incomes for many households, especially those in rural areas. Food policymakers cannot underestimate the potentials of vegetable farming, especially in farm revenue generation and attainment of food security for many smallholder farmers. In the quest towards a diversified food production system, the need to integrate African indigenous vegetables (AIVs) into small scale farmers' production portfolios cannot be underestimated. This is essential given that AIVs' utilisation for food and nutrition enhancement is as old as the history of man. More precisely, the Khoisanoid people, who resided in Southern parts of Africa at least 120,000 years ago, utilized and consumed AIVs for food and medicinal purposes (Odhav et al. 2007).

Schippers (2000) defined AIVs as plant species whose leafy parts (which may include the succulent stems and young fruit) are consumed as vegetables. Accordingly, ancient people of South Africa used various local terms to refer to this group of vegetables. Specifically, they are referred to *Muroho* in Tshivenda, *Morogo* among the Sesotho and isiPedi and *Imfino* among the isiZulu and isiXhosa (Njume et al. 2014). Schippers (2000) further noted that many popular indigenous vegetables were collected and obtained from the wild fields as they grow naturally other than from cultivation using traditional horticultural husbandry. Ebijuwu and Mabawonku (2015) argued that such wild crops are often viewed as weeds in commercial cropping systems, but they are sources of food in small-holding farming systems.

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Numerous varieties of AIVs exist and are utilised among South African farmers for different purposes. Some of them were identified and advocated for by research institutions such as the Agricultural Research Council (ARC) and the Department of Rural Development and Land Reform (DRDLR). AIV species such as nightshade, Chinese cabbage and pumpkin leaves are said to be highly prevalent in the Vhembe district of Limpopo Province (van Rensburg et al. 2005). Therefore, for this study, production of these three most common varieties of AIVs, namely, African nightshade, Chinese cabbage and Pumpkin leaves were analysed.

African nightshade - which is known as *muxe* in Tshivenda and *Umsobo* in isiXhosa – is uniformly grown in many parts of South Africa. More than 1500 species of nightshade exist, many of which are important sources of food and ethno medicine (van Rensburg et al. 2005). Chinese cabbage is known as *Mutshaina* in Tshivenda and is one of the most well-known plants in the Vhembe district, where it is much cultivated. Lastly, pumpkin is known as *Thanga* in Tshivenda and it is referred to as *Thaka* in Sepedi. It is extensively consumed in various parts of Africa. In South Africa, it is intermittently intercropped as a minor crop in maize farms.

In South African rural communities, AIVs are essential food being consumed with starch staples (Lewu and Mavengahama 2010). In the last five years, consumption of these vegetables among South African households has more than doubled (Senyolo et al. 2014). Yang and Keding (2009) argued that AIVs are outstanding sources of micronutrients such as Vitamin A, Calcium, Manganese, Magnesium and Iron. It has been noted that they can assist in addressing micronutrient deficiency (Abukutsa 2010) and food insecurity in times of drought and poor harvests (Madakadze et al. 2004; Parawira and Muchuweti 2008).

Enhancement of productivity and efficiency of AIVs holds significant potential in addressing food and nutrition insecurity in South Africa. There is rising interest and awareness of these vegetables in terms of their nutritional benefits and potential to generate substantial income for farmers. However, there is still a lack of market access for AIVs, which is linked to lack of adequate production (Mahlangu, 2014). Some evidence suggests that several factors are responsible for low vegetable production at the household level (Asogwa et al. 2011; Abdulai 2006). Some attribute this to an inefficient allocation of resources (Abdulai 2006). Subjective evidence suggests that there are a number of factors that are responsible for low production of vegetable at the household level (Mahlangu 2014; Faber et al. 2010; Muhanji et al. 2011). The question

then arises as to how efficient are farmers in the use of their scarce farm resources for the production of AIVs?

Furthermore, several studies have analysed the productivity and efficiency of vegetables in Africa (Sekhou and Kaur 2004). There have not been adequate focuses on estimation of production efficiency of AIV farmers in Limpopo province, and particularly in Vhembe district. Numerous studies that have been conducted in the study area focused more on the utilisation and commercialisation of these vegetables (Mahlangu 2014; Senyolo et al. 2014). This implies that factors influencing technical efficiency of AIV production remain unknown. We therefore seek to fill this research gap by analysing the determinants of AIV production and technical inefficiency of the farmers. It is hypothesised that none of the inputs variables significantly influences the production of AIVs and that farmers' socioeconomic characteristics do not significantly influence their technical inefficiency.

2 Materials and Methods

2.1 Description of the study area

The study was carried out in the Vhembe district of Limpopo province. The district comprises of four local municipalities which are Thulamela, Makhado, Mutale and Musina. The district is one of the five districts in Limpopo province. It is situated in the northern part of Limpopo province. The Kruger National Park lies to the east, while the north and north-west share international borders with Zimbabwe and Botswana respectively. The district's administrative capital is Thohoyandou. The district has a population of 1,232,218 people, with 90% residing in rural areas. It should also be noted that among the five districts in Limpopo province, production of AIVs is predominant in Vhembe district. People living in rural areas of the district rely mainly on the consumption of these vegetables, which many of them now grow as opposed to being harvested from wild fields.

2.2 Data collection technique

The study made use of primary data which were collected from smallholder AIV farmers. Data collection was carried out using a structured questionnaire. Farmers' socioeconomic characteristics such as age, gender, years of education, sources of finance, farming experience, sources of irrigation water, irrigation system and primary occupation

were captured. Vegetable production data such as the size of land area cultivated, hired labour utilization, amount of seeds planted, the quantity of fertilisers and pesticides and input prices were also collected. Lastly, the questionnaire captured both production and marketing challenges that were facing the farmers.

2.3 Sample and sampling technique

The study adopted multi-stage sampling procedures (Strydom 2005) to select a representative sample of 120 AIV farmers in Vhembe district of Limpopo Province. The first stage of the sampling entailed the selection of three irrigation and one dry land schemes, namely, Dzindi, Khumbe, Phalmaryville and Tshidzini respectively based on a substantial number of farmers producing the selected AIVs. At the last stage, a proportional sample size was selected randomly according to the total number of AIV farmers in each of the schemes. Those farmers that were not part of any government schemes were also randomly selected to be part of the final sample size. As a result of errors in completing some of the questionnaires and inability to provide some essential information, only 114 questionnaires were useful for inclusion in the final data analyses. Table 1 shows the total number of sampled farmers from the district.

2.4 Model specification

The data were analysed with the Stochastic Frontier model using the Cobb-Douglas production function. In literature, some researchers have modelled efficiency with parametric (Frontier) and non-parametric approaches (data envelopment analysis – DEA) with the intention of testing for the robustness of the estimated models (Kalb 2009). We chose the parametric approach because it

Table 1: Distribution of farmers according to Schemes and Villages in Vhembe district

Scheme/Village	Frequency	Percentage
Dzindi irrigation scheme	28	24.6
Khumbe irrigation scheme	33	28.9
Phalmaryville irrigation scheme	20	17.5
Tshidzini dryland scheme	16	14.0
Other villages	17	14.9

Source: Field Survey, 2016.

allows the estimation of the determinants on inefficiency in a single estimation procedure. However, within the parametric method, some researchers have compared between Translog and Cobb-Douglas production functions, thereby necessitating the use of a likelihood ratio test (Lewis *et al.* 2011). One of the major limitations of the Translog production function is the existence of multicollinearity due to imposed interactions among the variable production inputs (Pavelescu 2011). In this study, we could not subject our analyses to meaningful implementation with the Translog production function due to our small sample size.

The Stochastic Frontier model is formally known for defining efficiency levels for cross-sectional data. The original specification of the Stochastic Frontier model involved specification of a production function with composite error being accounted for by random effects as well as a technical inefficiency effect. These errors could have caused AIV production to deviate from the frontier. The first error term is known as the traditional normal error term whereby the variance is constant, and the average is zero (Coelli and Battese 1996). The second error term is referred to as the maximum likelihood estimation of the production function that determines inefficiency levels.

AIV production is functionally specified to be dependent on the size of the land, hired labour, amount of seeds, fertilisers, pesticides and mechanized land preparation. Therefore, productivity is measured following physical production relations derived from the Cobb-Douglas production function, which has been specified as equation 1. Thus, the specific model that was estimated is given as:

$$Y = AX_1^{\beta_1}X_2^{\beta_2} \dots X_n^{\beta_n} \nu \quad (1)$$

where $\beta_1, \beta_2 \dots \beta_n$ are the coefficients or output elasticities. Y is the estimated output, while X_n are the quantities of variable inputs that had been used during production. “ A ” is referred to as the average total productivity. In this study, the estimated Cobb Douglas production function is specified as:

$$\log Y_1 = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + \beta_5 \log X_5 + \beta_6 \log X_6 + \varepsilon_i \dots (2)$$

Where:

- Y = quantity of AIVs produced in kilogrammes (kg)
- X_1 = land area under vegetable cultivation (square metres)
- X_2 = amount of fertiliser used in kilogrammes (kg)
- X_3 = amount of pesticides used in litres (l)
- X_4 = hired labour used (man days)

X_5 = quantity of seeds planted (g)
 X_6 = mechanized days
 ε_i = random error term

The error term in equation 2 is composed of two components (Aigner et al. 1977) with $\varepsilon_i = v_i - u_i$. v_i is the symmetric component that caters for random variation in output as a result of factors which are beyond the control of the farmers like unexpected disease outbreak, extreme weather conditions and what is said to be independently and identically distributed with $N(0, \sigma_v^2)$. The second error term (u_i) captures technical inefficiency in production of AIVs and is also assumed to be an independently and identically distributed non-negative truncation of the $N(0, \sigma_u^2)$ distribution. If $u_i = 0$, it means that AIV production lies on the stochastic frontier and production is technically efficient. If $u_i > 0$, it implies vegetable production lies below the frontier and is inefficient. The technical inefficiency model is specified in equation 3.

$$u_i = \partial_0 + \partial_k \sum_{k=1}^8 Z_{ik} + m_i \quad (3)$$

Where u_i is AIV inefficiency index, ∂_k are the estimated parameters and m_i is the stochastic error term. Z_{ik} are the inefficiency explanatory variables being defined in Table 2.

3 Results and Discussion

3.1 Demographic characteristics of AIV farmers in Vhembe district

The results in Table 3 show that the majority of the AIV farmers were old. Specifically, 40.6% belonged to the age group of 61-80 years, while only 17.7% belonged to the 21-40 age group. Age plays a vital role in farming, since older farmers tend to have more years of farming experience, which may positively influence production efficiency (Obopile et al. 2008). Based on gender, 56.1% of the respondents were females. This implies that AIV production was a female dominated enterprise (van Averbeke and Juma 2006) in the district. The results further show that the majority (57.9%) of the farmers had household sizes of 4 to 6 members. About 43.9% had a maximum of 13 years of schooling. Fakoya et al. (2007) posited that literate farmers can be more receptive to the adoption of new farm production technologies. A substantial number of the farmers (91.2%) were farming on a full-time basis. This is an explicit indication that the majority of them lacked formal employment. This can also have positive influence on technical efficiency since the majority of the respondents were fully committed to farming.

AIV farmers' years of farming experience were relatively high with 29.8% having grown the crops for more than 45 years. This was closely followed by 22.8% that

Table 2: Description of inefficiency independent variables

Variable	Definition	Expected sign
Z_1 = Age	Number of years	-
Z_2 = Household size	Number of household members	-/+
Z_3 = Farmers' years of experience	Numbers of years growing AIVs	-
Z_4 = Years of schooling	Number of years	-
Z_5 = Gender	Male = 1, 0 otherwise	-/+
Z_6 = Purpose of farming	Farm incomes = 1, 0 otherwise	-
Z_7 = Access to credit	Yes = 1 0 otherwise	-
Z_8 = Extension services	Yes = 1, 0 otherwise	-
Z_9 = Market competition	Yes = 1, 0 otherwise	+/-
Z_{10} = Access to formal market	Yes = 1, 0 otherwise	+
Z_{11} = Access to irrigation scheme	Yes = 1, 0 otherwise	-/+

Table 3: Frequency distribution of demographic characteristics of AIV farmers in Vhembe District

Variables	Frequency	Percentage
Total	114	100
Age (years)		
21 – 40	20	17.7
41 – 60	37	30.7
61 – 80	45	40.6
>80	12	9.9
Gender		
Male	50	43.9
Female	64	56.1
Household size		
≤3	26	22.8
4 – 6	66	57.9
≥7	22	19.4
Years of Schooling		
0 – 12	49	43.9
13 – 18	43	37.7
Tertiary	21	18.4
Occupation		
Farming full-time	104	91.2
Formal employment	3	2.6
Other businesses	7	6.1
Primary purpose of farming		
Consumption	27	23.7
Business	87	76.3
Total	114	100
Farming experience		
1 – 15	37	32.5
16 – 30	26	22.8
31 – 45	17	14.9
≥45	34	29.8
Source of finance		
Farm savings	54	47.4
Formal employment	4	3.5
Pensioner's grant	45	39.5
Other businesses	7	6.1
Others	4	3.5
Access to Irrigation system		
Yes	81	71.1
No	33	28.9

Source: Field Survey, 2016

had 16 to 30 years of farming experiences. These results suggest that the cultivation of AIVs is an old practice among the farmers in the study area. Also, the accumulation of experience is expected to positively influence agricultural productivity and production efficiency (Msuya and Ashimogo 2005). The results in Table 3 also show that about 47.4% of the farmers' financial needs were obtained from farm savings, and 45% financed their farming activities through pension and social grants. In addition, 76.3% of the farmers indicated that their primary purpose for farming was to sell AIVs for income generation. The majority (71%) of the farmers had access to irrigation systems, which is also expected to have a positive impact on production efficiency (Koundouri *et al.* 2006).

3.2 Estimated Parameters in Cobb-Douglas Production Function

The results in Table 4 are those from the Cobb-Douglas stochastic production frontier function. The parameters of land area cultivated, fertilizer, labour, seeds and tractor hiring days were statistically significant ($p < 0.01$). Addition of all the input parameters gives some measures of returns to scale, which in this case indicate decreasing returns to scale. The null hypothesis that states that none of the variable inputs had significant impact on productivity of AIVs was rejected. The results are robust in the sense that dropping of some input or inefficiency variables do not bring about changes in the sign of the estimated parameters. Specifically, land area cultivated is the most fundamental variable influencing production of AIVs in the Vhembe district with the highest elasticity compared to other inputs. The parameter is statistically significant ($p < 0.01$). The elasticity of land area, is 0.4441, implying that holding other inputs constant, for every 10% increase in the land area cultivated, AIV output will increase by 4.441%. This result is consistent with the findings of Baloyi *et al.* (2011) and Amos (2007). However, the result is contrary to that of Bozoglu and Ceyhan (2007) who computed negative elasticity for land area parameter.

The elasticity of fertiliser utilization was 0.1749 and statistically significant ($p < 0.01$). The result suggests that holding other inputs constant, for every 10% increase in the quantity of fertilisers applied, AIV output will increase by 1.749%. Fertiliser plays a significant role in enhancing vegetable productivity, especially where soil fertility seems to be declining. Ogundari (2008) and Baloyi *et al.* (2011) have reported similar results.

The results in Table 4 further show that the parameter of hired labour is statistically significant ($p < 0.01$). Its

elasticity value is 0.1311, which implies that holding other inputs constant, for every 10% increase in the number of hired labour, AIV output will increase by 1.311%. This is in line with the findings of Loko (2009) and Barro (2001) who found that increasing labour quantity was positively associated with higher output.

Another variable which was found to be significant ($p < 0.01$) is the quantity of seed planted. The elasticity of seed is 0.2663, indicating that holding other inputs constant, every 10% increase in the quantity of seed planted will increase the AIV output by 2.663%. Weinberger and Msuya (2004) argued that the lack of supply and utilisation of high high-quality seeds leads to a significant yield gap. Seed appears to be the least important variable in increasing production yield. This might be due to farmer's lack of access to high-quality seed varieties, and as such, depend largely on recycled seeds (Douglas 2005). It had been noted that recycled seeds lose some potentials for better yield as compared to improved seeds.

Tractor hiring days for land preparation is with positive parameter (0.2360) and statistically significant ($p < 0.01$). The results showed that holding other inputs constant, increasing tractor hiring days by 10 percent would increase AIV outputs by 2.360%. Moreover, the returns to scale was computed as 0.4166. This indicates

that AIV outputs will increase by 4.166% provided all inputs were increased by 10% simultaneously.

3.3 Estimates of technical efficiency

The results of the technical efficiency index scores in Table 5 were obtained using the Stochastic Frontier Analysis. The outcome shows a slight variation in efficiency levels among the vegetable farmers. The predicted efficiency level ranged between 0.55 and 0.99, with a mean efficiency level of 0.79. The majority of the farmers (43.86%) had efficiency scores that are greater than 80%. This was followed by 35.09% of the vegetable farmers with efficiency scores of $0.70 < 0.80$. Also, 21.05% had efficiency score of less than 0.70.

3.4 Technical inefficiency effect

The results of the determinants of technical inefficiency are shown in Table 6. Gender, years of schooling, extension services and access to irrigation system were found to be statistically significant ($p < 0.05$). The result indicated that the coefficient for gender was statistically different

Table 4: Empirical results from Cobb-Douglas stochastic production frontier function

Variables	Parameters	Coefficient	T-statistics
Constant	X_0	0.4838***	19.53
Area cultivated	X_1	0.4441***	9.99
Fertiliser	X_2	0.1749***	3.61
Pesticide	X_3	-0.8358	-0.18
Labour	X_4	0.1311***	2.58
Seeds	X_5	0.2663***	10.86
Tractor days	X_6	0.2360***	2.77
Variance parameters			
Sigma square		0.6178***	
Gama		0.2007	
Number of observation		114	

Source: Field Survey (2016)

***Significant at 1%

Table 5: Distribution of technical efficiency index score

Efficiency level	Number of farmers	Percentage
≤ 0.70	24	21.05
$0.70 < 0.80$	40	35.09
$0.80 < 0.90$	32	28.07
≥ 0.90	18	15.79
Total	114	100
Mean	0.79	
Minimum	0.55	
Maximum	0.99	

Source: Author's analysis (2016)

from zero and negatively related to technical inefficiency. This implies that being a male farmer reduces technical inefficiency of AIV production. Tshiunza et al. (2001) also found that male farmers were more efficient than female farmers as they produce mostly to sell and generate income as opposed to household consumption.

The parameter of years of schooling was with negative sign and statistically significant ($p < 0.05$). The result implies that an additional year of education will lead to 0.0122 unit decrease in technical inefficiency level when other factors are held constant. This is in line with *a priori* expectation. Access to extension services was with positive sign and statistically significant ($p < 0.01$). This implies that farmers with access to extension services had higher levels of technical inefficiency. This is contrary to the findings of some researchers (Khairo and Battese 2005; O'Neill and Mathews 2000) who found a significant inverse relationship between technical support and technical inefficiency. This is based on the understanding that technical support will enable farmers to be more ready in adopting new technologies that can enhance vegetable production. The parameter of irrigation was found to be negatively associated with technical inefficiency and statistically significant ($p < 0.05$). Therefore, farmers that belonged to an irrigation scheme and had access to advanced irrigation system were more technically efficient than farmers who belonged to dry land schemes and had no access to irrigation system.

Table 6: Estimates of inefficiency effect model

Inefficiency effect	Coefficient	t-value
Constant	0.3213	0.45
Z_1 = Age	-0.2211	1.18
Z_2 = Household size	0.0284	0.42
Z_3 = Farmers' years of experience	0.0122	0.27
Z_4 = Years of schooling	-0.1939**	2.39
Z_5 = Gender	-0.1124**	2.13
Z_6 = Purpose of farming	0.0563	0.89
Z_7 = Access to credit	-0.0649	-0.96
Z_8 = Extension services	0.9629***	5.29
Z_9 = Market competition	0.0679	1.24
Z_{10} = Access to formal market	0.0986	1.55
Z_{11} = Access to irrigation scheme	-0.1253**	2.37

Source: Authors analysis (2016)

Note: ** Significant at 5%, *** Sig 1%

4 Conclusion and Recommendations

This study showed that production of indigenous vegetables (African nightshade, pumpkin leaves and Chinese cabbage) is substantially concentrated in the study area. The results revealed that the sum of elasticity of production was 0.407, indicating a decreasing return to scale. The land variable was found to be the most important factor of production to increase productivity with a higher elasticity compared to other variable inputs. Farmers in Vhembe district are subjected to smaller land size which they utilise to grow different crops, AIVs included. The results have demonstrated that indigenous vegetables have the potential of higher yield. Therefore, in order for the farmers to increase their productivity, it is highly recommended that they expand the area under indigenous vegetable cultivation.

A high technical efficiency level found in the study is an ample sign that indigenous vegetables have the potential to generate higher household income. As a result, their production should be enhanced. It was also found that beside land input, fertilisers, hired labour and tractor days were also with positive parameters. As a result, it is recommended that farmers should increase utilisation of

these inputs in order to maximise production and increase their marketable surpluses of indigenous vegetables.

Access to extension services increased technical inefficiency. It is evident that extension interaction was not sufficient and regular in the study area. Therefore, it is recommended that the approach of conducting training and practical workshops should be used as opposed to handling farmers' inputs or technology without knowledge of how to efficiently use them. The government should also provide supportive information centres where farmers can visit at any given time to source for information rather than waiting for extension officers' visits. Furthermore, the results of the empirical analysis found that the parameter of years of schooling was positively associated with technical inefficiency. The study proposes strategies such as providing better extension services and farmers training programs as a way to enhance farmers' knowledge and skills of farming. It is further recommended that the government should encourage youth participation in agriculture through emerging business funding opportunities. This will help close the educational gap which exists in the study area, thereby, increasing technical efficiency.

Conflict of interest: Authors declare no conflict of interest.

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