TECHNICAL EFFICIENCY ANALYSIS OF PIGEON PEA PRODUCTION IN MACHAKOS COUNTY, KENYA

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ABSTRACT

Pigeon pea is a drought-tolerant crop mainly grown by small-scale growers in arid and semi-arid regions mostly for income generation and enhancing food security. Nevertheless, its production remains low. Smallholder pigeon pea farmers are often faced with resource-use inefficiency and high costs of inputs in production implying that proper and efficient allocation of resources is vital to guarantee farmers attainment of additional benefits from their input. Hence, this study aimed at estimating technical efficiency and examining factors influencing technical efficiency of pigeon pea production in Machakos County, Kenya. The sample size was 346 respondents targeting pigeon pea farming households’ population. The study relied on primary data collected using structured questionnaire administered to the farmers. The County was purposively selected for the study. The inefficiency effect model and a Cobb-Douglas stochastic frontier production analysis method were utilised to estimate technical efficiency and determine the factors that influence pigeon pea farmers’ efficiency. The maximum likelihood parameter estimates illustrated that the size of the land, labour and quantity of seeds had a positive influence on the output of the pigeon pea. The technical efficiency levels ranged from 0.09 to 0.86, according to the findings. The estimated mean level of technical efficiency of the sample farmers, which was approximately 0.59, demonstrates the likelihood of increasing the quantity of pigeon pea yield by 41%. Some of the factors that influenced technical efficiency positively were farming experience, education, off-farm income and access to credit, whereas gender, age and occupation of the household head, negatively influenced technical efficiency. The study recommends enhancement of extension services and programs by the County to improve farmers’ capacity to increase pigeon pea productivity.

Keywords: Pigeon pea, Technical efficiency, Productivity, smallholder, Food security

INTRODUCTION

Agriculture has been the backbone of Kenya’s economy throughout its post-independence history and remains one of the main boosters to the Country’s Gross Domestic Product at 26%. According to the World Bank, (2018), the sector is responsible for 60% employment and 65% of exports. It is dominated by smallholder production on farms ranging from 0.2 to 3 ha, which accounts for 78% of total agricultural production and 70% of commercial production. Though, it has been described as the foundation of the country’s socio-economic development, the sector is characterised by meager productivity attributed to low investments, inferior technology and inefficient production systems (FAO, 2019).

According to UNICEF, the agriculture sector helps to meet the Sustainable Development Goals (SDGs) by revitalizing efforts to end poverty and food insecurity. Furthermore, from 2005 to 2015, it significantly aided in the decline of poverty (World Bank, 2018). Consequently, the expansion of agriculture significantly contributes to the decrease of poverty, especially for those who are marginalised and live in rural areas. This demonstrates how crucial smallholder agriculture is in ensuring improved food security, poverty reduction and income generation. Most smallholder farmers are in low income bracket hence productivity becomes critical in poverty reduction (Irungu et al., 2015). According to Karanja et
al. (2019), over 60% of people who live in rural areas rely on the agricultural industry for their livelihood. In response to the economy’s poor performance as a whole, Kenya has, as stated by Pelrine (2009), developed and implemented a variety of economic plan to improve the national economy over time. Several policy frameworks aimed at reducing poverty in Kenya have been developed and implemented using these plans. The Agricultural Sector Development Strategy (ASDS) and the Strategy for Revitalising Agriculture (SRA) are two examples of these economic plan (Maganga et al., 2012). In addition, a number of international bodies such as FAO, IFAD, and WFP are also determined to increase agricultural productivity in the Kenya (Alulu et al., 2021).

Declining agricultural productivity has in turn resulted in increased food insecurity in the country. Consequently, there is renewed interest in promoting drought-tolerant crops which are known to perform well in arid and semi-arid lands, owing to its ability to thrive in drought prone lands.

The arid and semi-arid lands (ASALs) account for approximately 89% of Kenya’s land mass and cut across Rift Valley, Eastern, Northeastern, and coastal regions (Omoyo et al., 2015). These lands are characterised by lack of water, extreme heat, frequent droughts, bare and marginal soils, eroding rain and wind, these phenomenon brings about crop failure hence food insecurity (Ayenan et al., 2017). The most common crops grown in arid and semi-arid lands in Kenya are beans (Phaseolus vulgaris L.), maize (Zea mays), pigeon peas (Cajanus cajan (L.) Millsp), cowpeas (Vigna unguiculata L.) and green grams (Vigna radiate Wilczek (Mergeai et al., 2001).

Pigeon pea production has been widely promoted among small-holder farmers in arid and semi-arid parts of Kenya. However, harvests are below 1t/ ha against a potential 5t/ ha (Wambua, 2021). According to Wambua et al. (2017), the primary drawback has been its low productivity. For Kenya to produce enough pigeon peas for its population, it should adopt various techniques such as increasing agricultural productivity by utilising efficiently the limited resources that are accessible (Mutegi & Zingore,(2008).

According to FAO, (2019), Pigeon pea is sources of protein in Kenya, especially in arid and semi-arid lands (ASALs). It is a legumes and a perennial member of the family fabaceae. Considered helpful since it is a source of food as well as fuel. They are nutritious since they contain vast amounts of proteins and valuable amino acids that can improve the diet of farmers. According to reports, pigeon pea, a legume, has 20–22% protein, 1.2% fat, 65% carbohydrates, and 3.8% ash (FAO, 2009). It is the sixth-most significant grain legume crop and is planted in a variety of cropping systems in the semi-arid tropical regions of Asia, Africa, and the Caribbean (Mula and Saxena, 2010).

According to FAO (2009), pigeon pea covers 4,000,000 ha globally with estimated productivity and production of over 4,000,000 t and 751 kg/ha, respectively. The leading producers are India and Myanmar at 80% (Anatole et al., 2017).

In Africa; Malawi, Tanzania, Kenya, Mozambique and Uganda grow 4% of the world’s production (GoK, 2016).

According to Omoyo et al., (2015) there are 24 Counties in Kenya that have a high likelihood of producing high yields of pigeon peas. Makueni, Machakos and Kitui are among them. Varieties Mbaazi1 (ICPL87091), KAT 60/8, and mbaazi2 (ICEAP 0040) are commonly grown (Pal et al., 2016).

Machakos County is located in the arid and semi-arid lands, characterised by frequent drought that result to food insecurity and crop failures (FAO, 2009). Consequently, there is renewed interest in promoting drought - tolerant crops which perform well in arid and semi-arid lands, Pigeon pea a good source of protein that helps alleviate food insecurity and its deep tap root may transport nutrients like phosphorus to the top layers of the soil, where they can benefit other crops (Anatole et al., 2017).

It creates jobs and is a source of nourishment. Pigeon pea production in Machakos County face a number of production constrains. Most of the growers do not want to invest in the production of improved varieties due to dismal profits, low income and cannot afford sufficient input, high cost of labour and material involvement prices, which in turn leads to the reduction in the farmer’s input rate application (Wambua, 2021). Thus, a decrease in input and other factors such as climate change, poor technology and market imperfections limit small-scale producers to subsistence production, which slows down the sector. Therefore, this may lead to negative influences on pigeon
pea produce together with the productive efficiency of (Ochalibe, 2018).

Efficiency can be achieved by either reducing the resources required to produce a particular output or maximising the output from a particular set of resources (Ali et al., 2018). Approaches to efficiency measurement are parametric which include thick frontier approach (TFA), distribution free approach (DFA) and stochastic frontier approach (SFA) and nonparametric which include data envelopment analysis (DEA) and free disposal hull (FDH). According to (Sanusi et al., 2010), frontier production functions, which estimate the maximum output as a function of inputs, were made possible by efficiency measurement. In a similar view, the minimum cost would be determined by a cost of production frontier function in relation to input and output prices. Frontier approach has an advantage over non frontier approach because it mirrors the technology set that the most efficient firm employs, provides a useful performance benchmark, provides the farm specific efficiency measures to the researchers and finally the word frontier is in line with theoretical definition of production, profit and costs. Efficiency in production, guarantees a stable increase in pigeon pea production. Productivity is a gauge of production efficiency.

The productivity (profits and outputs) of smallholder pigeon pea farmers in ASALs regions has remained low on the side of farmer’s field regardless of its agronomic potentials. The availability of high yielding and early maturing cultivars in the eastern part of Kenya is also a comparative advantage to smallholder farmers. Despite the existence of the factors of production, productivity of the smallholder farmers has remained low. This poses questions; Farmers in Machakos County producing maximum output with the available inputs? What are the determining factors for the farmers to achieve maximum output?

The main drivers impeding high productivity still remain unclear. However, re-focusing of agricultural policies towards improving efficiency amid decreasing natural resources such as land and water is critical in maintaining high productivity. This study therefore aimed at estimating technical efficiency levels and determining the factors influencing the efficiency among pigeon pea farmers in Machakos County, Kenya.

**MATERIALS AND METHODS**

This study was conducted in Machakos County (01’14’S 37º 23’ E) which has a semi-arid climate. The region’s population is approximately 1, 421, 932, with 264,500 households where the density is 240/km² (KNBS, 2019).

The sampling unit was pigeon pea farming household. A mixture of sampling procedures were used, where a combination of purposive and simple random technique was used to select the sub-Counties, Wards and household heads. In the first stage, seven sub-counties (Machakos, Yatta, Masinga, Kangundo, Matungulu, Kathiani and Mwala) out of eight sub-counties were purposively selected since they were the main pigeon pea producing areas. In the second stage, seven Wards, (one from each sub-County) were purposively selected from pigeon pea producing Wards. The selected wards were Kola, Katanga, Ekalakala, Kangundo West, Kyeleni, Mitamboni and Masii. Lastly, a sample proportional to the Ward population was picked using simple random sampling technique where Kola, Katangi, Ekalakala, Kangundo West, Kyeleni, Mitamboni and Masii had samples of sizes 50, 44, 39, 52, 36, 59 and 66, respectively. A sample of 346 pigeon pea farmers was used, having been determined by Cochran’s formula (Kothari, 2005) such that:

\[
n = \frac{z^2pq}{e^2}
\]

Where

- \(n\) = desired sample size.
- \(p\) = estimate quantity of a trait presents in the population.
- \(q\) = \((1-p)\)
- \(z\) = selected critical value of desired confidence level
- \(e\) = desired level of precision (0.05)

Theoretical framework

The study was based on the theory of productive efficiency, the Cobb-Douglas production function (production theory) and the stochastic frontier approach (SFA). A farmer’s best use of resources during the production process is referred to as productive efficiency. Producers should maximise their technical and economic
perspectives, according to modern economic theory (productive efficiency) (Kokkinou, 2010). From a technical point of view, producers optimise by not wasting productive resources, whereas from an economic point of view, producers optimise by resolving price allocation issues. Even though technology and production setting are essentially comparable, farms and businesses may exhibit different levels of productivity at a given time due to differences in production efficiency (Park and Lee, 2015). As a result, it is absolutely necessary to have a method for determining the extent to which producers fail to optimise or achieve full technical and economic efficiency. The analysis of production frontiers is one of the primary analytical approaches to efficiency measurement while the stochastic frontier analysis is one of the most important methods for estimating productive efficiency.

**Stochastic frontier analysis**

Aigner and Schmidt, (1977) were the initial developers of the stochastic frontier model. A Cobb-Douglas function serves as the basis for the production model.

\[ \log y = \beta' x + \nu - u \] .......................... 1

Where \( y \) is the observed outcome. 
\( \beta' x + \nu \) is the optimal production frontier. \( \nu \) is the stochastic part.

Inefficiency refers to the extent to which the observed individuals fail to reach the maximum (the frontier)

**Technical efficiency**

The stochastic frontier production function was expressed as:

\[ Y_i = f(X_i \beta) \exp(v_i - u_i) \] ......................... 2

Where the output level for pigeon peas is \( Y_i \), \( X_i \) is the vector of farm inputs, \( \beta \) is the parameter to be estimated, \( \exp(v_i) \) effects on output of exogenous shocks, \( \exp(-u_i) \) defines inefficiency.

\[ TE = \frac{y}{f(X_i \beta) \exp(v_i)} \] ......................... 3

TE values terms (0, 1) unitary indicated a technically fully efficient farm

Technical efficiency equation was expressed as:

\[ \ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + (v_i - u_i) \]

\( \ln \) Represents natural logarithm to base e, \( Y_i \) is the output of the pigeon peas in kg/acre \( \beta_1 \) to \( \beta_5 \) = parameters to be estimated

\( X_1 \) Farm size-under pigeon pea cultivation

\( X_2 \) Quantity of fertiliser in kg/acre

\( X_3 \) Farm labour in (Man days/acre)

\( X_4 \) Agro chemicals in litres/acre

\( X_5 \) Quantity of seeds in kg/acre

\( v_i \) Random errors assumed to identically and independently distributed to \( u_i \)

\( u_i \) Non-negative casual variables related to technical efficiency of production, whereby there is an assumption that they are independently distributed.

The modeling of the inefficiency of production of \( U_i \) undergo modelling based on the features that was believed to have an effect on farmers’ production efficiency. The determination of socio-economic aspects affecting technical inefficiency also occurred. The equation was as outlined below:

\[ \delta_0 + \delta_1 S_1 + \delta_2 S_2 + \delta_3 S_3 + \delta_4 S_4 + \delta_5 S_5 + \delta_6 S_6 + \delta_7 S_7 + \delta_8 S_8 + \delta_9 S_9 \]

Where \( U_i = \) technical inefficiency
\( \delta_i \) to \( \delta_{12} \) are the parameters to be estimated

\( S_1 = \) Age of the household head

\( S_2 = \) Gender of the household head

\( S_3 = \) Household size

\( S_4 = \) Education level

\( S_5 = \) Farming experience

\( S_6 = \) Seed variety used

\( S_7 = \) Accessibility of extension services

\( S_8 = \) Group membership

\( S_9 = \) Off-farm income

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RESULTS AND DISCUSSION

Technical efficiency levels of pigeon pea farmers in Machakos County

The data on the distribution of pigeon pea farmers according to their technical efficiency levels in Machakos County, indicated that most majority (46.24%) of the farmers in the study area were technically efficient at 51-60% while only 0.87% of the respondents were in most efficient category (81-90%). About 19.65% of the respondents belonged to the efficiency category of 41-50% while 16.47% of the respondents were in the efficiency category of 31-40%. (Table I)

About 2.60%, 4.05% and 7.51% of the respondents were in efficient category of ≤10, 11-20% and 21-30% respectively, while 1.73% and 0.87% of the farmers belonged to the technical efficient group of 61-70 and 71-80% respectively. These results imply that almost 50% of pigeon pea farmers in the County were technically efficient at 51-60% and thus need to improve their technical efficiency level by achieving maximum output from a given level of resources available for pigeon pea production. The sampled pigeon pea farms’ technical efficiency ranged from 0.09 to 0.86, with a mean of 0.59.

Four of the six variables taken into account in the production function and used to explain the variation in pigeon pea production among farmers were statistically significant. The production function had both negative and positive coefficients for its variables. At a 5% significance level, land size had an influence on pigeon pea output. The elasticity was 0.122. This concurs with a previous study by Kamau (2019) whereby a 1% increase in land size under pigeon pea significantly increased output by 0.12%.

Factor affecting technical efficiency

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Pigeon pea output was affected by quantity of seeds at a 5% significance level, and the elasticity was 0.161. This indicates that pigeon pea output would increase by 0.16% for every one percent increase in seed quantity. Alulu et al., (2021) and Maganga et al., (2012) also found that the seed rate had a positive effect on pigeon pea. In studies carried out in western Kenya and Malawi, respectively. The significant effect on quantity of seeds may also indicate that the quantity and quality of the pigeon pea seeds used, limited pigeon pea production, preventing farmers from...
achieving maximum productivity. This could be because pigeon pea farmers used local seeds and used about 5 kg of seeds per acre instead of the recommended 8-10 kg/acre, (Wambua, 2021).

At a 5% significance level, manure had a positive effect on pigeon pea yield, and the elasticity was 0.085. As a result, 1% increase in manure quantity would increase the quantity of pigeon peas produced by 0.09%, which is a significant increase. A rise in the use of manure is essential for crop sustainability, as stated by Kamau, (2019) who asserta that manure is essential for both an increase in productivity and preservation of soil. According to Chepngetich et al., (2015), manure nourishes the soil and increases the nutrient supply hence increasing productivity.

At 1% significance level, labour had the greatest positive elasticity of 0.579, which was highly significant. This suggests that pigeon pea output increased by 0.58% for every one percent increase in labour. Dessale et al., (2018), found that labour had a positive determinant of output on Teff production in Ethiopia. The fact that elasticity from labour was highest may also indicate that the amount of labour required to perform farm activities during pigeon pea production was the most constraining factor, preventing farmers from producing as much as possible. This may be because of overreliance on hired labour to complement the labour required in pigeon pea production. Therefore, services of hired labour are frequently used by farmers to meet their production requirements (Mamo et al., 2018).

### Determinant of technical inefficiency

This analysis’s main objective was to offer empirical proof of the production variability and gaps in efficiency among pigeon pea growers in the study area. The study looked into farm and farm-specific characteristics that affected smallholder farmers’ technical productivity. The parameters of the various assumed variables in the technical inefficiency effect model that are anticipated to explain differences in how well farmers do their jobs were calculated using a one-stage estimation method and the maximum likelihood estimation method.

Table III shows the different factors that influenced technical inefficiency of pigeon pea farmers in Machakos County, Kenya.

The age of the household head influenced technical efficiency negatively. According to Biam et al., (2016), older farmers with low levels of technical efficiency are less likely to adopt new technology and are more risk averse. According to Dessale and Tegegne (2017), farmer are expected to become less productive as they ages and lose the ability to handle farming tasks whereas younger farmers are more likely to be exposed to methods and techniques. This is in contrast to the findings of Kibaara (2005) who explained that farmers gain skills over time as a result other accumulated farming experience. Pigeon pea farming experience influenced technical efficiency positively at 1% level of significance. This suggests that more experienced farmers were more efficient than the less experienced ones. According to Kamau (2019), growers who have planted a particular crop for a long time are better able to predict when to plant the appropriate planting materials, and the kinds and quantities of inputs that should be used in production, which results in an increase in their TE compared to farmers who are less experienced.

The household head’s level of education had a significant 5% positive effect on technical efficiency. Ali et al. (2018), (Hossain and Majumder, 2018) and Fani et al. (2015) and detailed that education positively influenced on technical efficiency. According to Kamau (2019), farmers with more formal education are more likely to adopt new technologies regarding input use and are better able to interpret and use market information than farmers with less formal education, which works on their technical efficiency. Some (40.17%) of pigeon pea farmers in the
study area had primary school education, so increasing their formal education would raise their technical efficiency even more.

At the 5% level, access to credit had a positive effect on TE and significance. Biam et al., (2016) and (Mamo et al., 2018), reported that access to credit had a significant positive impact on TE. (Mamo et al., 2018) explained that the affordability of yield-improving resources made credit more accessible, resulting in a more diverse farming system and possibly increased productivity. Additionally, the availability of credit expands the cash constraint and enables farmers to timely purchase inputs that they would not otherwise be able to afford. Credit access had a negative influence on TE and argues that borrower farms are more inefficient than non-borrower farms.

Household size negatively influenced pigeon pea farmers TE at 1% significant level. The negative influence was reported by Ochalibe (2018). According to Ochalibe (2018), many farmers rely on domestic labour to increase production due to its availability, low cost, and ease of timely allocation of various farm activities. Occasionally, this source of labour may include unskilled workers, thereby lowering technical efficiency.

Gender negatively influenced technical efficiency at 5% significant level. A negative influence was reported by Dessale and Tegegne (2017) and (Nganga et al., 2010). Most farms 63.58% of the entire sample were managed by women, this implies female farmers participated more on pigeon pea farming than their male counterparts. According to Dessale and Tegegne (2017), despite the fact that women play a significant role in agricultural operations, they may be required to divide their time between actual farm work and household chores like cooking, gathering firewood and fetching water. Due to these extra responsibilities, they are left with less time to work on their farms, hence reducing productivity efficiency.

At a 5% significance level, off-farm income had a positive effect on technical efficiency (TE). This suggests that farmers who participated in exercises that procured them off-farm pay had further developed technical efficiency. According to Chepgetich et al.,(2015), farmers earning money off the farm are probably going to take on new innovations like superior seeds and might buy agricultural inputs. This may be due to the improved accessibility of yield-enhancing inputs and the supplementation of their low farming income by income from activities outside of farming.

Occupation of the household head negatively influenced technical efficiency at 10% significant level. A negative influence was reported by Yegon et al., (2015). According to Al-hassan, (2012), having more time for farm management enhances TE as opposed to when a farmer devotes more time to other activities, hence lagging behind in agricultural activities.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender of the household head</td>
<td>0.153** (2.18)</td>
<td>0.070</td>
</tr>
<tr>
<td>Age of the household head</td>
<td>0.154*** (3.11)</td>
<td>0.049</td>
</tr>
<tr>
<td>Education of the household head</td>
<td>-0.066** (-1.71)</td>
<td>0.039</td>
</tr>
<tr>
<td>Occupation of the household head</td>
<td>-0.244*** (-4.93)</td>
<td>0.044</td>
</tr>
<tr>
<td>Household size</td>
<td>-0.039 (-0.91)</td>
<td>0.021</td>
</tr>
<tr>
<td>Farming experience</td>
<td>0.271*** (2.81)</td>
<td>0.043</td>
</tr>
<tr>
<td>Marital status</td>
<td>-0.038** (-1.77)</td>
<td>0.036</td>
</tr>
<tr>
<td>Off-farm income</td>
<td>-0.045 (-1.25)</td>
<td>0.085</td>
</tr>
<tr>
<td>Distance to the market</td>
<td>0.004 (0.04)</td>
<td>0.073</td>
</tr>
<tr>
<td>Group membership</td>
<td>0.051 (0.70)</td>
<td>0.089</td>
</tr>
<tr>
<td>Training</td>
<td>-0.023 (-0.26)</td>
<td>0.084</td>
</tr>
<tr>
<td>Access to Extension Services</td>
<td>-0.155** (-1.84)</td>
<td>0.085</td>
</tr>
</tbody>
</table>

Field survey 2022 ***statistically significant at 1%, ** statistically significant at 5%, * statistically significant at 10% level, t- values in parenthesis.

CONCLUSION AND RECOMMENDATION
The findings of this study demonstrated that the sampled farmers' levels of technical efficiency varied significantly. Pigeon pea farmers could increase their technical efficiency by 41% by making better use of the resources they already have, as the mean technical efficiency was 0.59, ranging from 9% to 86%. Age and household size, which had a negative influence on technical efficiency in the production of pigeon peas can be addressed as well as enhancing farming experience to reduce technical
inefficiency. Pigeon pea farmers in the study area have a chance of lowering input costs without reducing yield by improving their technical efficiency.

The findings of this study lead to the following policy recommendations:

First the study proposes for the formulation of strategies to make available certified seeds to increase productivity and enhance efficiency in production. From the findings, use of uncertified seeds causes low yields. Availability, accessibility and sustainability of the certified pigeon pea seeds would be a better option for the farmers in Machakos County.

Secondly, the estimated technical efficiency results demonstrated that pigeon pea farmers are not entirely efficient. It is important to emphasise the optimal utilization of inputs like fertilisers, pesticides, manure, and high-quality seeds for maximum productivity. Efficient fertiliser application techniques should be adopted. This includes strategies such as Micro dosing (micro-fertilisation) which refers to the application of small doses of fertilizer in the seed planting hole at sowing, or at the base of plants later during the plant development and conservation agriculture that enhances soil fertility.

Thirdly, access to agricultural extension education, though not significant is a way which enables farmers to utilise inputs efficiently. Therefore, it recommends that efficient extension services and programs to be designed by the relevant organisations to enhance farmers’ capacity to improve productivity.

Finally, the study suggests implementing agronomic strategies aimed at reducing and adapting to the effects of climate change. Sustainable intensification techniques such as increasing units of outputs per units of all inputs through new combinations of inputs and related innovations are essential. Such intensification is appropriate response even to intense land pressures and degradation associated with the climate change.

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