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Original Research Article

Technical Efficiency of Crop Production in Sub-Saharan Africa: A Systematic Review of Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) Studies

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Abstract: Technical efficiency is a key factor for improving agricultural productivity in sub-Saharan Africa, where crop production is limited by resource constraints. This study conducts a systematic review of empirical studies that applied Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) to assess technical efficiency in crop production across Sub-Saharan Africa. In total, 22 peer-reviewed studies are reviewed and synthesized to identify efficiency levels, methodological trends, and key determinants of technical efficiency. The findings indicate that crop production in sub-Saharan Africa generally operates below the production frontier, indicating that there is significant scope to increase through more efficient use of existing inputs. According to the efficiency estimates, they vary by estimation method, with DEA-based studies generally reporting higher scores than those used in SFA. So that the lower efficiency estimates in SFA studies largely stem from their explicit treatments of random shocks, indicating weather-related variability. The review highlights that farmer education and access to extension are the most common determinants of technical efficiency across the studies, while other factors with positive effects include access to credit and the adoption of improved inputs such as quality seeds, fertilizers, and farmer experience, as well as participation in farmer organizations. In contrast, climate variability tends to reduce technical efficiency.

Keywords: Technical Efficiency, Agricultural Productivity, Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), Sub-Saharan Africa, Crop Production, Systematic Review.

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1. INTRODUCTION

In sub-Saharan Africa, agriculture is a fundamental sector that continues to play an essential role in economic growth and development (World Bank, 2020). It serves as the principal source of food, livelihood, and foreign exchange earnings across sub-Saharan Africa (SSA). (Badiane *et al*., 1995). Although to that importance of agriculture, sub-Saharan Africa (SSA) continues to suffer from widespread poverty and food insecurity, with 40% of the population living below the USD 1.90-a-day poverty line in 2018 and 24% undernourished in 2020. Together these indicators highlight sub-Saharan Africa as the region with the highest prevalence of poverty and hunger in the world (FAO, 2021). A large proportion of the poor and undernourished population lives in rural areas and depends on small-scale agriculture for survival (Sibhatu *et al*., 2015). The livelihood of majority rural farm households in SSA depends largely on small-scale crop and livestock production systems. (Haile *et al*., 2017). These farming systems are commonly characterized by low productivity, limited adoption of improved technologies, and high vulnerability to climate and price shocks. (Otsuka *et al*., 2017). Although agriculture contributes an average of 15% to total GDP, its importance varies widely across SSA, from less than 3% in Botswana and South Africa to over 50% in Chad, indicating that diverse economic structure. Agriculture employs more than half of the total labor force in SSA (IMF, 2012). In rural areas, agriculture provides a livelihood for millions of small-scale producers. So that Smallholder farms account for approximately 80% of all farms in SSA and directly employ about 175 million people (Alliance for a Green Revolution in Africa, 2014). In most SSA countries, the agricultural sector provides employment for more than half the population. So Improving agricultural performance is therefore essential

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for achieving food security and also advancing sustainable development goals in SSA (FAO, 2021).

Technical efficiency can be described as the ability of a production unit to produce the maximum possible output from a given set of inputs (Farrell, 1957). So the concept of technical efficiency helps explain how effective inputs are used in the production. (Coelli *et al*., 2005). and also is particularly relevant in agriculture, where producers face significant resource and environmental constraints. (Battese *et al*., 2004). So improving technical efficiency is important for SSA farmers who face limited access to capital and technology, as efficiency gains can substantially increase agricultural output without requiring additional inputs. (Bravo-Ureta *et al*., 2018; Abdallah *et al*., 2021). Empirical evidence shows that crop production in SSA is characterized by substantial inefficiency (Mugera *et al*., 2012), while improvements in efficiency can increase farm income and food availability (FAO, 2021). And also strengthen resilience to climatic and economic shocks. (Fuglie *et al*., 2020).

Technical efficiency is commonly measured using frontier production approaches, which compare observed production with best practices performance and allow inefficiency among producers to be quantified, making frontier analysis a standard method in agricultural efficiency studies. (Kumbhakar *et al*., 2005. Data Envelopment Analysis (DEA) is a non-parametric method that uses linear programming to construct an empirical production frontier without requiring a specific functional form and is capable of handling multiple inputs and outputs, and it has been widely applied in agricultural efficiency studies in SSA (Charnes *et al*., 1978). In contrast, Stochastic Frontier Analysis (SFA) is a parametric approach that distinguishes inefficiency from random statistical noise, accounts for measurement error and external shocks, and requires specifications of a functional form, and it has also been widely applied in agricultural studies. (Aigner *et al*., 1977). while DEA is deterministic and does not statistically account for random noise, so that making it flexible but sensitive to outliers. SFA is stochastic and relies on functional form and distributional assumptions, and both methods are widely used in SSA agricultural efficiency research (Coelli *et al*., 2000).

Despite the importance of agriculture for livelihoods, employment, and food security in sub-Saharan Africa, agricultural productivity continues to exhibit low levels. So this is largely due not only to limited access to capital, technology, and improved inputs, but also to significant technical inefficiency in the use of available resources. Although many studies have examined technical efficiency in SSA using Data Envelopment Analysis and Stochastic Frontier Analysis, the findings are dispersed and often method-specific so that making it difficult to draw clear conclusions for policy and practice, so this study is therefore conducted to synthesize existing evidence on technical efficiency in SSA agriculture improve understanding of efficiency gaps, and provide insights that can support policies aimed at enhancing productivity and food security.

2. METHODOLOGY

This study conducts a systematic review of existing empirical research to better understand technical efficiency in agricultural production across sub-Saharan Africa. So this study review focuses on empirical studies that applied or used Data Envelopment Analysis and Stochastic Frontier Analysis to measure efficiency at the farm or crop level within the region. A total of 22 peer-reviewed studies were included in the analysis by covering multiple countries across East, West, and Southern Africa. So relevant articles were identified through a careful search of major academic databases and screened using clear eligibility criteria, including a direct focus on agricultural production in SSA and the empirical estimation of technical efficiency. So that from the selected studies, key information such as county coverage, crop type, method used (DEA and SFA), sample size, average technical efficiency, and determinants of efficiency was extracted and collected into a structured dataset. The collected structured datasets were then assessed comparatively to evaluate the similarities and differences in efficiency estimates among methods, regions, and even production systems. So this methodological approach allows this study to move past isolated case studies, making a balanced and systematic understanding of technical efficiency patterns in SSA agriculture with implications that are both methodologically rigorous and applicable to policy and future studies.

3. RESULTS AND DISCUSSION

3.1 Descriptive Overview of the Included Studies

Table 1 presented the general characteristics and countries used of the 22 studies included in this review study. According to the method used, most studies are used in stochastic frontier analysis (14 studies), while only 8 studies are used in data envelopment analysis (DEA). This shows that the reflects a preference for methods that account for random shocks in agricultural production. According to regional distribution, East Africa dominates, represented by 11 studies, and next to West Africa, which had 7 studies, while Southern Africa had 3 studies and Central Africa had 1 study. According to the countries covered in this study, 11 countries were covered. Regarding to the crop type. Cereal crops such as maize, wheat, rice, and sorghum are examined in 13 studies, highlighting the focus on staple food systems. While also mixed cropping systems appear in 6 studies, and finally cash crops are covered in only 3 studies, suggesting that efficiency analysis of commercial crops remains limited.

Table 1: Characteristics and Country Coverage of Reviewed Studies (n = 22)

Characteristic	Category	Number of Studies
Method used	DEA	8
	SFA	14
Region	East Africa	11
	West Africa	**7**
	Southern Africa	3
	Central Africa	1
Countries covered	Ethiopia, Tanzania, Ghana, Rwanda, Nigeria, Kenya, Zambia, Uganda, Malawi, Cameroon, Eswatini	11
Crop type	Cereals	13
	Mixed crops	6
	Cash crops	3

3.2 Frontier Models and Estimation Techniques

As shown in Table 2, the reviewed studies employed different modeling approaches within the DEA framework. The standard DEA model was more frequently applied or used than bootstrap-based approaches, while SFA studies more frequently employed the Cobb–Douglas model than the translog form, mainly because of its ease of estimation. So that the widespread use of the Cobb–Douglas model indicates a preference for models that are easy to interpret and estimate, and also the inclusion of translog models by some authors points to an effort to account for input substitution and also heterogeneity in production technologies.

Table 2: Frontier Models Used in Reviewed Studies

Method	Model Type	Number of studies
DEA	Standard DEA	5
	Bootstrap DEA	3
SFA	Cobb-Douglas	9
	Translog	5

3.2 Technical Efficiency Levels in Crop Production

Table 3 presented the distribution of reported technical efficiency scores, showing that the efficiency values vary widely across studies, ranging from very low to relatively high performance, so that the average efficiency score is around 0.60, indicating that crop producers in sub-Saharan Africa operate well below the production frontier. So the results show that technical inefficiency continues to be a key constraint on agricultural productivity in the region. So that the evidence of efficiency levels exceeding 0.80 indicates that productivity gains are possible without new technologies, so that highlighting the role of management practices and institutional factors.

Table 3: Reported Technical Efficiency Levels across Studies

Statistic	Technical Efficiency
Minimum	0.19
Maximum	0.90
Mean	0.60
Median	0.62

3.3 Comparison of DEA and SFA Results

Table 4 presented a comparison of technical efficiency estimates derived from DEA and SFA methods, as shown overall in the studies. DEA reported higher average efficiency scores than those used in SFA. This difference reflects the underlying methodological assumptions of the two approaches. While DEA attributes all deviations from the production frontier to inefficiency, SFA allows for the presence of random shocks. So that agricultural production in sub-Saharan Africa is highly exposed to climatic and environmental variability; as a result, the lower efficiency estimates reported by SFA studies may provide a more realistic assessment of production performance. Despite their differences, both methods together provide valuable insights into technical efficiency.

Table 4: Average Technical Efficiency by Estimation Method

Method	Mean Technical Efficiency
DEA	0.66
SFA	0.57

3.4 Determinants of Technical Efficiency

Table 5 was presented the key determinants of technical efficiency identified in the reviewed studies. Education level of farmers is commonly identified as a positive determinant of technical efficiency. This positive effect indicates that education enhances farmers' ability to use inputs and technologies effectively. Extension services are widely identified as having a positive and significant impact on technical efficiency so that extension service shown that it contribute to efficiency by improving access to relevant information studies reported both positive and negative effect of farm size on efficiency so that this effect of farm size appear to depend on local conditions and farming systems, several studies shown that credit access positively influences technical efficiency so this access to credit likely support efficiency by facilitating inputs purchase and farm investment input quality studies shown that higher-quality inputs are commonly linked to improved efficiency outcomes so that this positive findings indicate the contribution of improved inputs to higher productivity, studies showing that experienced farmers and association members tend to be more efficient, so this positive indicate that experience and social networks of the farmers appear to enhance efficiency through shared knowledge and cooperation, Studies reported that there are both positive and negative associations between household size and efficiency; this mixed effect may be due to variations in household labor supply and dependents, while climate variability is shown to have a negative effect on technical efficiency. These findings indicated that the vulnerability of agricultural production to environmental and climatic risks.

Table 5: Determinants of Technical Efficiency Commonly Identified Across Studies

Determinant	Effect on Efficiency	Frequency
Farmer education	Positive	High
Extension services	Positive	High
Farm size	Mixed	Medium
Credit access	Positive	Medium
Input quality (Seeds/Fertilizer)	Positive	Medium
Farmer experience	Positive	Medium
Membership in associations	Positive	Medium
Household size	Mixed	Medium
Climate variability	Negative	Medium

4. CONCLUSION

This study reviewed 22 empirical studies on technical efficiency in crop production in sub-Saharan Africa. The studies used Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). The findings show that crop production in the region is generally inefficient, also indicating that there is substantial potential to increase output through better use of existing inputs. The review further indicates that technical efficiency estimates vary across methodological approaches; the studies using DEA generally report higher efficiency scores, whereas SFA-based studies tend to produce lower estimates due to their treatment of random shocks such as weather variability. Despite these differences, both approaches offer valuable insights and jointly contribute to a more comprehensive understanding of efficiency levels.

According to the determinants of efficiency, there are a number of factors affecting the efficiency across the studies reviewed. Farmer education and access to extension services are strongly associated with higher efficiency levels. The findings show that access to credit and improved inputs supports more efficient production, while in contrast, climate variability is commonly associated with lower efficiency levels. Overall, the findings indicate that enhancing technical efficiency in Sub-Saharan Africa depends on stronger farmer support systems, improved access to information and finance, and effective policies to manage climate-related risks.

5. RECOMMENDATIONS

Based on the findings of this systematic review, several policy and practical recommendations can be drawn to improve technical efficiency in crop production across Sub-Saharan Africa.

1. Strengthen farmer education and extension services. Improve training and extension support to help farmers adopt better practices and use inputs more efficiently.
2. Improve access to credit for farmers. Expand affordable rural credit to enable timely input use and investment in productive technologies.
3. Promote the use of quality agricultural inputs. Ensure availability of improved seeds and fertilizers to enhance production efficiency.
4. Support farmer organizations and associations. Encourage farmer groups to improve knowledge sharing and collective action.
5. Address climate-related risks. Promote climate-resilient practices to reduce efficiency losses caused by weather variability.

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