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Economic Efficiency of Small-Scale Sunflower Farmers in Tanzania: A Stochastic Profit Frontier Approach

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***Abstract* - Globally, the demand for sunflower vegetable oil has been increasing annually. Smallholder farmers, who represent a relatively large proportion of sunflower seed production, continue to face challenges of low productivity. Although several studies have examined factors contributing to this low productivity, rigorous empirical evidence on the economic efficiency of sunflower farmers remains limited. Understanding economic efficiency is crucial for designing appropriate interventions to increase sunflower seed productivity. An increase in productivity is expected to improve farmers' income and ensure a sustainable supply of sunflower seeds in the country. This study investigates the factors influencing economic efficiency in sunflower production by employing stochastic profit frontier analysis. Secondary data from the NSCA 2019/20 survey, covering a total of 632 households, were used for analysis. The findings indicate that the average economic efficiency score of sunflower producers is 45.31%, implying that farmers are economically inefficient and have significant potential to improve resource use. The results further show increasing returns to scale (0.1196), suggesting that scaling up input use could enhance productivity. Key determinants of economic efficiency include farm size (1.0485), family labor (0.2000), and seed cost (0.1662). This study concludes that sunflower smallholder farmers have scope to improve efficiency through increased farm size and greater utilization of family labor in the production process.**
***Keywords:* Sunflower Production, Economic Efficiency, Smallholder Farmers, Stochastic Frontier Analysis, Productivity**

I. INTRODUCTION

A. Background Information

Sunflower (Helianthus annuus) is an important oilseed crop cultivated worldwide under diverse climatic and soil conditions, providing employment to large rural communities [6]. It serves as a major source of vegetable oil in the tropics and is ranked as the third most produced oilseed globally [9]. Additionally, sunflower is a rich source of Vitamin E, the body's primary fat-soluble antioxidant, which plays a significant role in the prevention of cardiovascular disease [1]. Russia and Ukraine are the leading global producers of sunflower seeds, contributing about 47% of the total output, while African countries account for approximately 5.5% [8]. The relatively low contribution from Africa is primarily attributed to limited access to essential inputs and technologies, such as improved seed varieties and modern production and processing techniques [17].

Tanzania ranks second in sunflower production in Africa, following South Africa, and contributes about 35% to the continent's total output [8]. The total area under sunflower cultivation in Tanzania is approximately 529,394 ha, with nearly 99% of production managed by smallholder farmers [24]. Sunflower accounts for about 35% of the country's edible oil supply, followed by groundnuts, cottonseed, and sesame [16]. According to the 2019/20 Agricultural Census Report, sunflower production in Tanzania reached 504,422 metric tons, compared to 352,902 metric tons reported in the 2016/17 census, with an average productivity of 1.0 t/ha. Furthermore, nearly 11% of agricultural households engage in sunflower farming.

The growth of the sunflower sector has been supported by the adoption of low-cost oil expellers and filter machines from China, along with government extension services. In addition, private sector actors such as the Rural Livelihood Development Company (RLDC) and the Netherlands Development Agency have played an active role in seed production [11]. Despite these improvements, the sector still underperforms, forcing the country to import about 50% of its edible oil demand [3], [23]. To address this issue, the Tanzanian government has launched a national strategy to revitalize the sunflower oil industry. This strategy focuses on:

1. Enhancing production and productivity through modern farming techniques,
2. Strengthening institutional and technical capacity,
3. Improving the quality of sunflower-based products,
4. Promoting sector growth through coherent policies aligned with national development goals, and
5. Facilitating market access through timely and effective support mechanisms. Nevertheless, productivity remains low at around 1.0 t/ha, compared to the potential yield of 3.0 t/ha [12].

Previous studies [10], [14], [18], [20], [21] have examined sunflower production in Tanzania. These studies consistently attribute low productivity to the use of low-yield seed varieties, inadequate pest and disease control, restricted access to financial services and market information, and considerable post-harvest losses. However, there is limited empirical evidence on efficiency levels among small-scale sunflower farmers. Improving resource-use efficiency could be a viable strategy to enhance productivity [28]. This research gap hinders the development of effective strategies to help sunflower farmers meet the growing demand.

Overall, this study on economic efficiency aims to improve farmers' welfare by reducing poverty and ensuring a stable supply of sunflower oil in the country. The primary objective is to provide empirical evidence on the level of economic efficiency by determining whether farmers are profitable through the stochastic profit frontier method. Interventions that enhance farmers' capacity to maximize profits are essential for increasing revenues and reducing poverty.

The findings of this study will guide policymakers and relevant stakeholders in designing appropriate interventions to improve production and productivity, thereby fostering a sustainable sunflower sector in Tanzania and enhancing the incomes of smallholder farmers.

II. METHODOLOGY

A. Study Area

The research was conducted on the Tanzania mainland, which comprises 26 regions. No sunflower production was reported in Zanzibar during the 2019/20 agricultural year. The country covers a land area of 885,800 km², with elevations ranging from sea level to over 1,600 m in the west. Most of the territory lies above 1,000 m, with extensive areas exceeding 1,500 m in the central and northern regions.

B. Sample and Selection Procedure

This study utilized secondary data from the National Sample Census of Agriculture (NSCA) 2019/20, collected by the National Bureau of Statistics of Tanzania. The census employed four questionnaires: the smallholder farmers' questionnaire, the large-scale farmers' questionnaire, and the community-level questionnaire. Each questionnaire provided a wide range of socio-economic and agricultural production indicators.

The NSCA 2019/20 dataset was derived using a two-stage sampling design. In the first stage, urban and rural enumeration areas were selected based on the 2012 Population and Housing Census frame. In the second stage, farming households were sampled from the selected enumeration areas. The data were cleaned and organized using SPSS, yielding a final sample of 632 smallholder sunflower farmers.

C. Data Analysis

This study followed the methodology proposed in [2] and [25] to measure efficiency using a profit function rather than a production function. This approach is particularly useful when dealing with heterogeneous input prices and resource endowments. The analysis employed the Stochastic Profit Frontier (SPF) model to assess the economic efficiency of sunflower producers.

The Cobb-Douglas (CD) functional form was adopted, following [26] and [27], due to its suitability for relatively small samples and its log-linear structure. The CD form was preferred over the Translog specification because its parameters directly represent elasticities, which are useful for evaluating returns to scale. Moreover, the CD function enables easier estimation using maximum likelihood methods [7], [22]. The CD model used to evaluate the economic efficiency of sunflower farmers is specified as follows:

$$ln\pi^*_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \sum_{i=4}^{8} \beta_i lnP_i + v_i - u_i \ldots\ldots\ldots (3)$$

Where π^*_i =normalized profit of the ith farmers, X_i= factor inputs for sunflower production: farm size, quantity of seeds, available family per acre, $\beta_1 - \beta_8$=parameter estimates, $P_4 - P_8$=normalized prices: normalized price of seeds (P_4), normalized weeding cost (P_5), normalized harvesting cost (P_6), normalized price of land preparation (P_7), normalized planting cost (P_8), and u_i=the inefficiency profit model for i^{th} farmers.

III. RESULTS

A. Socio-Economic Characteristics of Sunflower Farmers

Findings presented in Table I indicate that sunflower production is predominantly undertaken by males, who constitute 78.16% of the sample, while females account for 21.84%. This may be attributed to the fact that, in most Tanzanian communities, males are the heads of households and were therefore more likely to be interviewed.

The average age of sunflower farmers was 49.88 years, with a minimum of 21 years and a maximum of 97 years. This suggests that most sunflower producers fall within the active labor force and are relatively mature, consistent with the findings in [5]. On average, farmers had 7.59 years of formal education, corresponding to Tanzania's compulsory primary education level. The mean farm size was 1.5 acres, indicating that most farmers cultivate relatively small plots of land [14].

On average, farmers incurred a cost of 3,500 Tshs per kilogram of sunflower seeds. The average costs of weeding and harvesting were 17,000 Tshs and 8,000 Tshs, respectively. In addition, the average planting cost was 7,500 Tshs, while land preparation cost averaged 21,000 Tshs.

B. Parameter Estimation of the Maximum Likelihood Stochastic Profit Function

Table II presents the results of the maximum likelihood estimation (MLE) for the stochastic profit frontier model, variation in sunflower production is attributable to factors under the farmers' control. Moreover, the gamma (γ) value of 0.9986, also statistically significant at the 1% level, identifying the variables that significantly influence sunflower production. Farm size, family labor, and seed cost were found to be statistically significant determinants. The sigma-squared (σ^2) value of 44.66 was statistically significant at the 1% level, indicating that approximately 44% of the confirms the model's good fit and the presence of inefficiency effects, consistent with the findings in [4].

TABLE I THE SOCIO-ECONOMIC CHARACTERISTICS OF SUNFLOWER FARMERS

Variables	Mean	Standard Deviation	Minimum	Maximum
Farm size	1.5037	2.13334	0	30
Education Level	7.59	3.528	1	19
Age	49.88	15.748	21	97
Seed costs	3,233.27	8,314.912	0	180,000
Seed quantity used	8.2030	22.06996	0	366.67
Weeding Costs	16,899.29	54,497.012	0	900,000
Harvesting Costs	7,578.72	32,231.443	0	500,000
Planting Costs	7,302.33	33144.529	0	600,000
Land Preparation costs	20,890.95	57,635.933	0	900,000
Family Labour	1.14	0	1	6

The sum of the elasticity coefficients was 0.1196, suggesting that sunflower farmers operate under increasing returns to scale. This implies that proportional increases in all inputs would result in more than proportional increases in output, highlighting the potential for expanding sunflower production through improved resource utilization.

TABLE II ESTIMATES OF MAXIMUM LIKELIHOOD STOCHASTIC FRONTIER MODEL

Variables	Parameters	Coefficient	Standard error	t-ratio
Constant	β_1	0.12767959	0.089520736	142.62571
Farm size	β_2	1.0484872***	0.12559712	8.3480196
Seed quantity	β_3	0.02903214	0.044658593	0.65009079
Family labour	β_4	0.20001583*	0.12183902	1.6416402
Normalized seed cost	β_5	0.16616152***	0.050426483	-3.2951242
Normalized weeding cost	β_6	-0.011266363	0.022929507	-0.4913478
Normalized harvesting cost	β_7	-0.023145902	0.025249891	-0.91667335
Normalized land cost	β_8	-0.0039431278	0.016846887	-0.23405677
Normalized planting cost	β_9	0.0012165612	0.027046825	0.044979816
Model fitness				
Log-likelihood function	0	-11.25***	0	0
Likelihood ratio test (LR)	0	96.81***	0	0
Mean Efficiency	0	0.4531	0	0
Variance parameter for the error component				
sigma squared (δ^2)	$\delta^2 v + \delta^2 u$	44.662308***	3.4287878	13.025685
gamma (γ)	$\delta^2 u / \delta^2$	0.99864761***	0.00034317654	2910.0113

Notes: ***, ** and * denotes at 1%, 5% and 10% respectively.

The coefficient for farm size in Table II is positive and significant at the 1% level, indicating that a 1% increase in farm size could increase sunflower output by approximately 105%. This result is consistent with [29], which reported that cultivated land size has a positive effect on output. Similarly, family labor has a positive effect and is significant at the 10%

level, where a 1% increase in labor per acre could increase sunflower output by 20%. Conversely, the cost of seeds negatively affects sunflower production and is significant at the 1% level. A 1% increase in seed cost is associated with a 16.7% decrease in output. This suggests that higher seed prices may discourage farmers from adopting improved seed varieties, leading them to rely on lower-yielding local seeds, which ultimately reduces output.

C. Economic Efficiency Score Estimates in Sunflower Production

Economic efficiency was estimated among smallholder sunflower farmers in Tanzania. The results of the MLE parameter estimates of the stochastic profit function are presented in Table III. The mean economic efficiency was 45.31%, implying that sunflower producers are economically inefficient and have a 54.69% potential to improve efficiency without increasing input use. Furthermore, the economic efficiency of most sunflower farmers ranged between 10% and 50%, suggesting that they could still increase their income by producing sunflower more efficiently with the resources available to them. These findings are consistent with those of Asogwa *et al.* (2011), who also reported low economic efficiency among smallholder farmers, largely attributed to inadequate access to extension services.

TABLE III SUMMARY OF ECONOMIC EFFICIENCY SCORES FOR SUNFLOWER SEEDS PRODUCTION IN TANZANIA

Economic Efficiency (%)	Percentage
0-9	11.55
10-50	47.31
51-99	41.14
TOTAL	100
Maximum Efficiency	92.59
Minimum Efficiency	0.0000021091
Mean Efficiency	45.31
Standard Deviation	24.27

IV. DISCUSSIONS

This paper aimed to determine the characteristics of sunflower farmers, the level of economic efficiency, and the key factors influencing efficiency. Regarding demographic characteristics, the results show that the sunflower sector is dominated by males (78.16%), with females accounting for 21.84%. This may be attributed to females engaging more in non-farming activities. These findings are consistent with [19], which reported that 73.9% of sunflower producers in Chemba District were men. The results also indicate that the average years of schooling among farmers is seven, implying that most sunflower farmers have primary education and, therefore, basic literacy and numeracy skills. Education is crucial since it directly influences farmers' ability to make informed decisions, which can lead to higher productivity and profitability. In addition, sunflower farmers incur various costs, including seed, weeding, harvesting, and planting costs.

On average, farmers spend 3,500 Tshs per kilogram of sunflower seeds, using 8 kg per acre, amounting to approximately 29,000 Tshs per acre. The average weeding cost is 17,000 Tshs per acre, with maximum reported costs of 900,000 Tshs and some farmers incurring no costs at all, indicating that certain farmers do not weed their fields. This lack of weeding may contribute to low productivity, as weeds compete with crops for nutrients. The average harvesting cost is 8,000 Tshs per acre, with a maximum of 500,000 Tshs and a minimum of zero. Zero harvesting costs may reflect reliance on family labor, which is not included in production costs. Planting and land preparation costs averaged 7,500 Tshs and 21,000 Tshs, respectively, with maximums of 600,000 Tshs and 900,000 Tshs, and minimums of zero. Again, the minimum values may reflect the use of family labor, whose contribution is typically excluded from cost estimates. Family labor averaged one person per acre, with a maximum of six and a minimum of one.

The analysis revealed that economic efficiency among sunflower farmers is relatively low, averaging 45.31%. Key factors influencing efficiency include farm size, family labor, and seed costs. Farm size and family labor positively affect efficiency, while seed costs negatively affect it. Specifically, a 1% increase in farm size leads to a 105% increase in efficiency, underscoring the importance of land availability. This finding aligns with Mbugi (2020), who reported that farm size significantly affects economic efficiency in bean production. Similarly, a 10% increase in family labor leads to a 20% increase in efficiency, consistent with [13], which found that family participation in bee farming enhanced productivity. Conversely, a 1% increase in seed costs reduces efficiency by approximately 17%. This finding is supported by [15], which noted that higher seed prices discourage the adoption of improved varieties, leading smallholder farmers to rely on recycled seeds, which are less productive.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

This study set out to evaluate the economic efficiency of smallholder sunflower farmers in Tanzania, specifically to:

1. Assess the socioeconomic characteristics of sunflower smallholder farmers, and
2. Measure economic efficiency in sunflower production.

The results from the socioeconomic analysis show that farmers, on average, have formal education up to standard seven, which aids in decision-making. The average age of 49 years indicates that most farmers are mature and capable of making rational production decisions. However, the findings also reveal that farmers incur high production costs, particularly for seed purchases.

The maximum likelihood estimate of 0.1196 indicates increasing returns to scale among sunflower farmers. This suggests that greater input use leads to higher output, as farmers are operating in the first stage of production. It further implies that farmers are not efficiently allocating resources, leaving room for expansion. The economic efficiency analysis revealed that sunflower farmers are economically inefficient, with an average efficiency score of 45.31%. This implies that farmers lose approximately 54.69% of potential output due to technical and allocative inefficiencies, which contributes to persistent poverty. Farm size and seed cost were significant at the 1% level, while family labor was significant at the 10% level. Seed costs negatively affected efficiency, whereas farm size and family labor had positive effects on productivity. Overall, the findings demonstrate that sunflower farmers have substantial room to improve economic efficiency, thereby enhancing the sustainability of sunflower farming and contributing to broader economic development.

B. Recommendations

The study results generally indicate that, despite government efforts, the sunflower sector in Tanzania remains unstable and unable to ensure poverty reduction and adequate edible oil supply. Therefore, both the government and private sector should focus on addressing these challenges by providing farmers with knowledge on the efficient use of land, labor, and seeds to enhance sunflower production. In addition, the government should consider subsidizing sunflower seeds to encourage farmers to adopt improved varieties instead of relying on local seeds. Training programs should also emphasize the importance of using improved seeds to ensure a sustainable supply of edible oil in the country.

Declaration of Conflicting Interests

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