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Article

Econometric analysis of resource-use efficiency and profitability in cowpea-based farming systems of Ondo State, Nigeria

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Abstract: This study assessed the efficiency of resource use and profitability in cowpea-based farming systems among smallholder farmers in Ondo State, Nigeria. Data were collected from 160 respondents using a multistage sampling technique and a structured questionnaire. Analytical tools included descriptive statistics, gross margin analysis, and a Cobb-Douglas production function estimated via Ordinary Least Squares (OLS). Results indicated that cowpea production is highly profitable, yielding a return on investment (ROI) of 4.26, meaning that every ₦1 invested generates ₦4.26 in return. The gross margin and net profit per hectare were ₦932,881.08 and ₦885,100.39, respectively. The Cobb-Douglas model showed that farm size, fertilizer, cowpea seed, and agrochemicals significantly and positively influenced output, whereas labor had a significant negative effect. The estimated returns to scale (0.43) suggested decreasing returns to scale. Further analysis of Marginal Value Product (MVP) and Marginal Factor Cost (MFC) revealed underutilization of land and agrochemicals, and overapplication of labor. Major constraints identified included high transportation costs, price instability, environmental hazards, and limited access to capital and market information. The study concludes that while cowpea farming remains economically viable, addressing technical inefficiencies and systemic barriers is essential for enhancing productivity and profitability.

Keywords: cowpea production; input; productivity; profitability; resource-use efficiency; Nigeria

1. Introduction

Agriculture remains the backbone of Nigeria's economy, contributing approximately 23% of the nation's GDP and providing livelihoods for over 70% of the rural population [1,2]. Within this sector, cowpea (*Vigna unguiculata*) holds immense socioeconomic importance due to its dual role as a staple protein source and as a nitrogen-fixing legume that improves soil fertility [3,4]. Cowpea's short maturity cycle, adaptability to low-input systems, and resilience to erratic rainfall have made it an essential crop for smallholder farmers, particularly in the semi-arid and savanna zones of Nigeria [5]. Despite its critical role in rural livelihoods and food security, cowpea production in Nigeria faces persistent challenges. These include low productivity, inefficient resource utilization, and declining profitability under increasing land pressure and climate variability. Yields remain far below the genetic potential of improved varieties due to agronomic constraints, pests, and suboptimal input use [6,7]. The traditional farming systems in which cowpea is grown are often characterized by inadequate access to extension services, poor soil fertility, and inconsistent input supply chains. In this context, understanding the resource use efficiency and the economic performance of cowpea-based systems is pivotal for improving productivity, reducing waste, and supporting smallholder profitability.

The concept of resource use efficiency—a measure of how effectively inputs such as land, labor, seed, and fertilizer are translated into output—is critical for smallholder farming, where resource scarcity is prevalent [8,9]. Economically, efficiency can be subdivided into technical efficiency (maximizing output from given inputs), allocative efficiency (using inputs in cost-effective combinations), and economic efficiency (a combination of the two). Numerous empirical studies have employed parametric approaches like the Cobb-Douglas production function or stochastic frontier analysis (SFA) to evaluate efficiency in crop systems, especially in developing countries [10,11]. The Cobb-Douglas model, in particular, provides a useful and interpretable framework for assessing input elasticity and returns to scale, which are vital for designing appropriate intervention strategies. Cowpea is often cultivated as part of intercropping systems with cereals such as maize, millet, or sorghum, contributing to integrated crop-livestock farming models in northern Nigeria. These systems offer ecological and economic benefits by improving resource recycling, reducing pest pressure, and enhancing soil quality [12,13]. However, the profitability and efficiency of such systems depend on the compatibility of component crops, input availability, and market access. Recent on-farm trials have demonstrated that optimized cowpea-cereal combinations can increase total productivity and income if resource allocation is properly managed [14].

The profitability of cowpea production is influenced not only by biophysical and agronomic variables but also by market dynamics, input prices, and socioeconomic factors [15,16]. Recent studies have shown significant variation in cowpea marketing margins, profitability across market types, and input-output relationships in Nigerian agricultural zones [16–18]. These findings underscore the need for disaggregated analyses that incorporate both production-side and market-side constraints. Furthermore, profitability is often undermined by inefficiencies such as excessive or inadequate labor use, suboptimal seed rates, and misapplication of fertilizers or agrochemicals. Socioeconomic factors, including farmer education, access to credit, extension contact, and membership in cooperative societies, play a crucial role in resource allocation and farm-level decision-making. In many cases, women and youth are actively involved in cowpea cultivation, but their productivity is hampered by limited access to land, finance, and inputs [19]. Understanding these characteristics is essential for targeting policy interventions and capacity-building initiatives.

Studies assessing resource efficiency in cowpea farming remain limited compared to major cereals, despite the crop's growing economic relevance. Recent evaluations of intercropped systems have demonstrated the potential of cowpea to improve land use efficiency and labor productivity, particularly when integrated with climate-smart practices and improved seed varieties [20]. However, the extent to which Nigerian smallholder farmers use inputs efficiently in mono- or mixed cowpea systems remains inadequately understood. The current literature often overlooks the quantification of input elasticity and return-to-scale behavior using accessible and robust models like Cobb-Douglas. Additionally, few studies have systematically identified and ranked the production constraints limiting cowpea profitability and input efficiency. These include erratic rainfall, poor access to certified seed, pest infestation, high cost of fertilizer, and volatile market prices. Farmers also face institutional constraints such as weak extension systems and poor rural infrastructure, which reduce their ability to adopt yield-enhancing technologies [5,19].

This study aims to bridge these knowledge gaps by providing a comprehensive analysis of socioeconomic characteristics, cost and returns, resource use efficiency, and production constraints in cowpea-based farming systems in Nigeria. Specifically, it applies the Cobb-Douglas production function via OLS to estimate the marginal productivity of inputs and examine returns to scale. The findings are expected to inform agricultural policy, extension programming, and input support strategies that will enhance the productivity and profitability of cowpea farming in a resource-constrained environment. Overall, achieving sustainable increases in cowpea production requires a clear understanding of how farmers use their resources, what factors drive or constrain profitability, and where interventions can be most effective. By focusing on these dimensions, this study contributes to the broader discourse on agricultural transformation, food security, and rural income generation in Nigeria.

2. Research methodology

Ondo State lies in the humid tropical zone of Nigeria, characterized by an average annual rainfall of 1200–2000 mm and a mean annual temperature ranging from 22 °C to 32 °C. The state experiences two distinct seasons: a rainy season (March–October) and a dry season (November–February). The dominant soil types are sandy loam and loamy soils, which are moderately fertile but prone to nutrient leaching under heavy rainfall. The area enjoys a growing season of approximately 180–200 days, making it favorable for short-duration legumes such as cowpea. The soil pH typically ranges between 5.5 and 6.8, providing a suitable environment for cowpea root development and effective nodulation. The area selected reflects the diversity of farming systems and input access across the State. This study adopted a cross-sectional survey design, using a structured questionnaire to gather quantitative data from smallholder cowpea farmers. The design is appropriate for capturing variations in resource use, productivity, and profitability across different farm households at a single point in time. The study employed a multistage sampling technique to ensure the representativeness and geographic coverage of cowpea farmers within Ondo State, Nigeria. The state is administratively divided into four Agricultural Development Programme (ADP) zones: Ondo, Owo, Ikare, and Okitipupa. Among these, the Ondo ADP zone was purposively selected for the study due to its high concentration of cowpea production activities, making it a relevant site for examining cowpea-based farming systems. Within the selected ADP zone, a structured multistage sampling procedure was followed:

First Stage: Out of the 8 agricultural blocks in the Ondo zone, 50% (i.e., 4 blocks) were randomly selected using simple random sampling to ensure unbiased representation.

Second Stage: From the 32 operational cells within these selected blocks, 50% (16 cells) were randomly chosen.

Third Stage: A proportionate stratified random sampling technique was then applied to select 40% of the registered arable crop farmers from each cell, yielding a total sample of 160 cowpea farmers for the study.

A total of 160 cowpea farmers were sampled to balance statistical robustness with resource constraints, including time, logistics, and funding. This sample size was determined based on the formula for minimum sample size calculation for finite populations, ensuring a confidence level of 95% and a margin of error of 7.5%, which is considered acceptable for farm-level surveys [21]. Moreover, previous similar studies in resource-constrained environments have successfully used comparable sample sizes to yield statistically valid and generalizable findings [7].

To address the study objectives, a combination of descriptive and econometric analytical tools was employed. These tools were chosen for their robustness in evaluating both the quantitative and qualitative dimensions of cowpea-based farming systems. The models are specified as follows:

i. Descriptive Statistics: Descriptive statistics such as frequencies, means, and standard deviations were used to summarize the socio-economic characteristics of the respondents and production constraints.

ii. Gross Margin Analysis: To estimate the costs and returns associated with cowpea production, the following metrics were calculated:

$$\text{Total Revenue (TR)} = \text{Yield (kg/ha)} \times \text{Price (₦/kg)}$$

$$\text{Total Variable Cost (TVC)} = \text{Sum of input costs (labor, seed, fertilizer, etc.)}$$

$$\text{Gross Margin (GM)} = \text{TR} - \text{TVC}$$

$$\text{Profitability Ratio (Return on Investment, ROI)} = \text{TR/Total Cost of Production}$$

iii. Cobb-Douglas Production Function (OLS Estimation): The Cobb-Douglas production function estimated through Ordinary Least Squares (OLS) was employed in this study due to its empirical robustness, simplicity, and suitability for farm-level data analysis [7,11]. Its log-linear form facilitates the direct interpretation of coefficients as elasticities of production, allowing the study to quantify the responsiveness of cowpea output to changes in input levels. Additionally, the model enables the estimation of returns to scale by summing the input elasticities, providing insight into the overall efficiency of resource allocation. Given the nature of the data—continuous and positive input-output values—the Cobb-Douglas model offers a parsimonious yet analytically powerful tool without imposing complex distributional assumptions. It is particularly advantageous in data-scarce or resource-constrained environments where frontier models like stochastic frontier analysis may not be feasible. Moreover, the model's strong theoretical foundation in production economics and its widespread application in similar agricultural studies reinforce its appropriateness for assessing the technical and economic efficiency of cowpea-based farming systems in the area.

The Cobb-Douglas production function is expressed in its log-log linear form as:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \varepsilon_i$$

where:

Y = Cowpea output (kg/ha);

X_1 to X_5 = Inputs such as farm size (ha), labor (man-day), seed quantity (kg), fertilizer (kg), agrochemical (litres);

β_0 = Constant;

β_1 to β_5 = Output elasticities;

ε_i = Error term.

Returns to scale were computed as the sum of β coefficients. MPP is calculated as:

$$MPP = \beta_i \times (Y/X_i)$$

iv. Constraint Analysis: A Likert scale ranking method was used to assess and rank production constraints (e.g., high input costs, pest pressure, credit inaccessibility). Mean scores guided prioritization in the study. Constraints were assessed using a 3-point Likert scale, where farmers were asked to rate each constraint as: 1 = Not Serious, 2 = Serious, and 3 = Very Serious. The mean scores were then used to prioritize the constraints based on their perceived severity.

3. Results and discussion

3.1. Socio-economic characteristics of cowpea farmers

Table 1 presents the descriptive statistics summarizing the socio-economic profiles of the sampled cowpea farmers. The results show that 77% of respondents were male, underscoring the continued dominance of men in arable crop production in Nigeria. This aligns with previous studies, which found that male farmers typically have greater access to land, agricultural resources, and extension services, thereby enhancing their participation in decision-making and cash crop production [5,19]. The average age of respondents was 42.4 years, suggesting that most cowpea farmers are economically active and within a productive age bracket. This finding is consistent with Kamara et al. [22], who noted that cowpea production is largely practiced by middle-aged farmers with sufficient experience and physical capacity to manage the crop. However, the age distribution (ranging from 25 to 78 years) also reflects participation by older farmers, who often rely on indigenous knowledge and traditional practices to sustain production. The mean household size was 3.99, which reflects typical rural household dynamics in Nigeria. Larger households are often an advantage in labor-intensive farming systems, such as cowpea cultivation, where family members contribute to operations like planting, weeding, and harvesting [23]. Similarly, the mean farming experience of 12.6 years suggests that most farmers are seasoned practitioners who may have developed adaptive strategies for input allocation and pest management. Prior studies have established a positive correlation between farming experience and both input efficiency and technology adoption [24].

Table 1. Results of the summary of the cowpea farmers' profiles.

Variable	Mean	SD	Minimum	Maximum
Sex	0.77	0.29	0	1
Age	42.4	12.6	25	78
Marital Status	0.82	0.19	0	1
Household Size	3.99	1.24	1	5
Farming Experience	12.60	5.90	1	20
Cowpea Farm Size	0.70	0.60	0.10	1.00

Table 1. (*Continued*).

Variable	Mean	SD	Minimum	Maximum
Farm Size	1.00	0.50	0.10	2.00
Income	1,068,846.20	697,695.70	25,000	2,500,000
Extension services	0.67	0.54	0	1
Cooperative societies	0.89	0.15	0	1
Market Access	0.82	0.25	0	1

With respect to land access, the average cowpea farm size was 0.70 hectares, while the mean total farm size stood at 1.00 hectare, indicating that cowpea is often integrated into mixed cropping systems. This supports earlier findings by Singh and Ajeigbe [25], who noted that cowpea is typically cultivated as a companion crop due to its short duration and ability to improve soil nitrogen. The small farm sizes reflect the broader challenge of land fragmentation in Nigerian agriculture, which constrains economies of scale and mechanization. In terms of income, the mean annual farm income was ₦1,068,846.20, with significant variability across respondents. This reflects the heterogeneity in market access, input use, and output prices, as well as disparities in landholding and labor availability. Although some farmers earn substantial returns from cowpea, others operate at subsistence levels, consistent with the findings of Anthony et al. [17], who reported significant income disparities among cowpea marketers and producers in Nasarawa State. Institutional support and market access are also critical determinants of production efficiency. About 67% of farmers had contact with extension agents, which is crucial for disseminating knowledge on pest control, input use, and best agronomic practices. Access to extension services has been found to significantly influence resource use decisions and improve productivity [10,11]. Notably, 89% of farmers belonged to cooperatives, which play a vital role in input procurement, credit access, and collective marketing. The high level of cooperative membership corroborates findings by Ajeigbe et al. [14], who emphasized the role of farmer organizations in reducing transaction costs and improving bargaining power. Furthermore, 82% of respondents had access to markets, underscoring the commercial orientation of cowpea production in the study area. Market access ensures better price realization, reduces post-harvest losses, and incentivizes input investment. According to Issoufa et al. [6], proximity to output markets and timely market information are positively associated with profitability in cowpea-based systems.

3.2. Cost and returns analysis of cowpea production

The economic analysis of cowpea production, presented in **Table 2**, provides detailed insights into the structure of production costs, revenue, and profitability among smallholder farmers in the study area. The results reveal a total cost of production (TCP) of ₦271,268.47 per hectare, composed of both fixed and variable costs. Of this total, fixed costs accounted for ₦47,780.69 (17.61%), while variable costs dominated the production budget at ₦223,487.78 (82.39%). This cost structure is consistent with the findings of Ayanwale et al. [23], who noted that smallholder crop production in Nigeria is largely driven by variable input expenditures, particularly labor and inputs like fertilizer and seeds. Within the fixed cost component, the knapsack sprayer accounted for the highest share (₦26,826.92 or 9.89%), reflecting the capital intensity of pest and herbicide management tools in cowpea farming. Items such as wheelbarrows, shovels, and hand tools like hoes and cutlasses contributed minimally but remain essential for daily field operations. The relatively low depreciation values reflect the use of low-cost, durable tools commonly found in traditional smallholder systems, as similarly observed by Amaza et al. [24].

Table 2. Estimation of profitability analysis.

s/n	Cost Items	Mean value (₦)	Percent
	Depreciation value on fixed items		
	Cutlass	1921.00	0.71
	Hoe	1378.92	0.51
	Shovel	8653.85	3.19
	Wheelbarrow	9000.00	3.32
	Knapsack sprayer	26,826.92	9.89
A	Total Fixed Cost (TFC)	47,780.69	17.61
	Variable items		
	Labour cost on pesticide applications	1122.50	0.41
	Labour cost on other activities	106,311.98	39.19
	Pesticide	5590.10	2.06
	Herbicide	11,147.60	4.11
	Fertilizer	16,836.54	6.21
	Transportation	10,341.68	3.81
	Land rent	10,347.00	3.81
	Tractor rent/hire	21,800.00	8.04
	Shelling machine rent	3932.69	1.45
	Planting materials/seeds	36,057.69	13.29
B	Total Variable Cost (TVC)	223,487.78	82.39
C	Total Cost of Production (TCP) = A + B	271,268.47	100.00
	Revenue information		
	Yield (kg/ha)	546.15	
	Unit price (₦)	2117.31	
D	Total Revenue (TR)	1,156,368.86	
	Gross Margin (D − B)	932,881.08	
	Profit (D − C)	885,100.39	
	Return on investment (ROI) = D/C	4.26	

On the variable cost side, labor accounted for the largest expenditure, with ₦106,311.98 (39.19%) allocated to non-pesticide-related activities and a smaller amount (₦1,122.50 or 0.41%) dedicated to pesticide application. This underscores the labor-intensive nature of cowpea production, particularly in the absence of full mechanization. High labor dependence aligns with observations by Kamara et al. (2009), who noted that manual operations dominate cowpea-based farming systems in

Nigeria. Planting materials/seeds (₦36,057.69 or 13.29%) and fertilizer (₦16,836.54 or 6.21%) also represent significant variable costs, reflecting farmers' investment in improved varieties and soil fertility management. Other major cost drivers include tractor hire (₦21,800.00 or 8.04%), transportation (₦10,341.68 or 3.81%), and land rent (₦10,347.00 or 3.81%). These costs point to structural and infrastructural challenges, including limited ownership of mechanized equipment and access to affordable land. According to Issoufa et al. [6], such constraints contribute to inefficiencies in input allocation and resource productivity.

The average yield was 546.15 kg/ha, with a prevailing market price of ₦2,117.31 per kilogram, resulting in a total revenue (TR) of ₦1,156,368.86 per hectare. This yield performance is relatively favorable when compared to the national average of 300–500 kg/ha reported by the International Institute of Tropical Agriculture [26], suggesting that the sampled farmers were relatively productive and likely benefited from improved seed, input use, or better agronomic practices. From this revenue, the gross margin (TR − TVC) amounted to ₦932,881.08, while the net profit (TR − TCP) stood at ₦885,100.39 per hectare. The resulting Return on Investment (ROI) was 4.26, implying that for every ₦1 invested in cowpea production, the farmer realized a return of ₦4.26. This ROI exceeds the profitability benchmarks reported in similar studies [10,17], indicating that cowpea production under the right conditions is highly profitable and economically viable for smallholder farmers in Nigeria. This high profitability can be attributed to favorable output prices, relatively efficient input management, and perhaps access to cooperatives and extension services—as earlier discussed. In conclusion, the cost and return analysis confirms that cowpea production is not only profitable but also a financially sound investment for smallholder farmers in the study area.

3.3. Estimation and interpretation of the cobb-Douglas production function

The Ordinary Least Squares (OLS) estimation of the Cobb-Douglas production function was used to assess the resource use efficiency in cowpea production. The results, as presented in **Table 3**, provide estimates of the elasticity of output concerning key farm inputs, including farm size, fertilizer, labor, cowpea seed, and agrochemicals. The model explains a substantial proportion of the variation in cowpea output, with an R-squared value of 0.895, indicating that approximately 89.5% of the variation in output is explained by the input variables included in the model. The F-statistic (212.191, $p < 0.01$) confirms the joint statistical significance of the regression model. Among the input variables, farm size was found to have the largest and most significant positive effect on cowpea output, with a coefficient of 0.439 ($p < 0.01$). This implies that a 1% increase in cultivated land area leads to a 0.439% increase in output, holding other factors constant. This finding is consistent with previous studies [10,24,27], which noted that land expansion often contributes significantly to output in low-input farming systems, especially in contexts where access to mechanization and improved technologies is limited. Fertilizer use also showed a positive and statistically significant elasticity of 0.032 ($p < 0.05$). Although the effect size is modest, it indicates that increased fertilizer application does contribute to higher yields. This is in line with Issoufa et al. [6] and Oladoyin et al. [28], who demonstrated that integrated nutrient management enhances productivity in cowpea systems, particularly under soil fertility constraints typical of tropical smallholder farms.

Table 3. Results of cobb-Douglas production function.

Variable	Coefficient	Std. Error	*T*-value	*P*-value
Farm size	0.439***	0.071	6.24	0.000
Fertilizer	0.032**	0.015	2.16	0.031
Labor	−0.328***	0.097	−3.39	0.001
Cowpea seed	0.195**	0.089	2.18	0.029
Agrochemicals	0.092**	0.046	2.01	0.044
Constant	2.017	0.438	4.605	0.000
R-square	0.895			
F-value	212.191***			

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

The coefficient for cowpea seed input was 0.195 ($p < 0.05$), indicating that increasing the quantity or quality of seed used improves output significantly. This is especially relevant in the context of improved seed adoption, where certified or higher-yielding varieties have been shown to outperform local varieties in terms of vigor, pest resistance, and yield potential [12,22,29]. Agrochemical expenditure also contributed positively and significantly to cowpea output (coefficient = 0.092, $p < 0.05$). This reflects the role of pest and weed control in safeguarding yield potential, particularly in areas where insect pressure is high. As reported by Ajeigbe et al. [5], effective crop protection is critical in cowpea cultivation due to the crop's susceptibility to pests during both vegetative and reproductive stages. Interestingly, the coefficient of labor input was negative and significant at the 1% level (−0.328). This inverse relationship suggests potential over-utilization or inefficiency in labor use. It is possible that beyond an optimal point, additional labor may not translate into proportional increases in output, possibly due to task redundancy, poor timing, or underemployment of labor-saving technologies. Similar observations have been made in prior studies that reported diminishing marginal productivity of labor when not matched with complementary inputs [7,23,24].

The sum of the coefficients (i.e., the output elasticities of all inputs) is approximately 0.43, suggesting decreasing returns to scale (**Table 4**). This implies that proportional increases in all inputs would lead to a less than proportional increase in output. Such a result is typical in resource-constrained environments where inputs are not always applied in optimal combinations or where inefficiencies in input management limit productivity gains [10,30].

Table 4. Production elasticity.

Variable	Coefficient
Farm size	0.439
Fertilizer	0.032
Labor	−0.328
Cowpea seed	0.195
Agrochemicals	0.092
RTS	0.43

Again, resource-use efficiency analysis is crucial for determining whether inputs are being optimally utilized in production. This is done by comparing the Marginal Value Product (MVP) of each input with its Marginal Factor Cost (MFC). An input is considered efficiently used when the MVP equals MFC (i.e., MVP/MFC = 1). Values greater than 1 indicate underutilization—where additional use of the input would increase output and profit—while values less than 1 suggest overutilization, where excess use leads to reduced economic efficiency. As shown in **Table 5**, the MVP/MFC ratio for farm size was 47.18, indicating that land is highly underutilized. This suggests that increasing land allocated to cowpea production would substantially enhance output and profit. The large margin between MVP and MFC confirms that farm size remains a limiting factor and that expanding cultivated area, where feasible, could boost technical efficiency. Similar findings have been reported in studies by Ogundari [10] and Amaza et al. [24], where land consistently emerged as a productivity-constraining input in smallholder systems.

Table 5. Results of resource-use efficiency of the inputs.

Input	MPP	MVP	MFC	MVP/MFC	Interpretation
Farm size	230.54	488,124.65	10,347.0	47.18	Under-utilized
Fertilizer	2.50	5293.27	16,836.54	0.31	Over-utilized
Labor	−13.12	−27,779.11	106,311.98	−0.26	Over-utilized
Cowpea seed	3.58	7579.97	36,057.69	0.21	Over-utilized
Agrochemicals	12.14	25,704.14	11,147.60	2.31	Under-utilized

Fertilizer showed an MVP/MFC ratio of 0.31, suggesting underutilization as well, though to a lesser extent. The low MVP indicates that while fertilizer contributes to productivity, its use is not yet optimal. This could stem from suboptimal dosage, late application, or low fertilizer quality. Studies such as Issoufa et al. [6] and Oparinde et al. [31] advocate for integrated soil fertility management and timely application to improve fertilizer response in cowpea systems. The most critical observation in this analysis relates to labor, which had a negative MPP (−13.12) and an MVP/MFC ratio of –0.26. This indicates overutilization of labor, where additional labor input reduces output. Such inefficiency may be due to task duplication, overreliance on manual methods, or poor timing of field activities. This finding echoes the conclusions of Ayanwale et al. [23], who observed diminishing returns to labor in similar cropping systems where labor inputs exceeded optimal thresholds. Addressing this inefficiency may involve promoting labor-saving technologies, better labor scheduling, and mechanization of certain operations. Cowpea seed input had an MVP/MFC ratio of 0.21, also reflecting underutilization. This indicates potential productivity gains through improved seed rates or higher-quality varieties. Given cowpea's sensitivity to plant population density, poor seed quality or inadequate planting densities could limit yield potential. Singh and Ajeigbe [25] emphasized that access to certified seed varieties significantly boosts legume output under similar agroecological conditions.

The analysis also reveals that agrochemical inputs (herbicides, insecticides, etc.) are underutilized, with an MVP/MFC ratio of 2.31. This suggests that modest increases in agrochemical use—particularly when integrated with good agronomic practices—could enhance pest control and yield outcomes. Ajeigbe et al. [5] and Olubunmi-Ajayi et al. [32] reported similar results, noting that effective pest management through the judicious use of agrochemicals significantly improves cowpea productivity in pest-prone regions.

3.4. Constraints to cowpea production in the study area

Understanding the constraints faced by farmers is essential for designing interventions that can improve productivity, efficiency, and the overall sustainability of agricultural systems. **Table 6** presents the major challenges encountered by cowpea farmers in the study area, ranked based on mean Likert-scale scores. The constraints span economic, institutional, environmental, and agronomic factors that hinder optimal cowpea production. The most pressing challenge identified was high transportation cost, with a mean score of 2.66, ranking it first among all constraints. This reflects infrastructural deficits in rural areas, where poor road networks, high fuel prices, and limited access to affordable transportation services increase the cost of moving both inputs and harvested produce. This finding aligns with those of Ayanwale et al. [23] and Anthony et al. [17], who reported that transportation bottlenecks in Nigerian agriculture inflate marketing costs and reduce producer margins, especially for perishable or bulk commodities like cowpea.

Table 6. Constraints faced by the cowpea farmers.

Constraints	Mean Response	Rank
Transportation cost	2.66	1st
Unstable price	2.59	2nd
Environmental hazard	2.49	3rd
Pest and diseases	2.36	4th
Inadequate capital or credit	2.25	5th
Inadequate market information	2.25	5th
Shortage of labor	2.19	7th
Inadequate government support	2.07	8th
High cost of agrochemicals	2.07	8th
Lack of modern equipment	2.02	10th
Unavailability of input	2.01	11th

Unstable output prices emerged as the second major constraint (mean = 2.59), underscoring the volatility of cowpea markets. Price fluctuations often occur due to seasonality, weak market linkages, and lack of structured value chains. This uncertainty discourages investment in input-intensive practices and limits income predictability for smallholders. As noted by Amaza et al. [24], price instability is a key disincentive to scaling production in grain legume systems in West Africa. The third-ranked constraint was environmental hazards (mean = 2.49), which include erratic rainfall, drought, flooding, and extreme temperatures—conditions exacerbated by climate change. Such hazards reduce yields and increase vulnerability to pest outbreaks and crop failure. The climate sensitivity of cowpea, particularly at flowering and podding stages, has been well-documented [12,32], highlighting the need for resilient varieties and adaptive agronomic practices.

Pest and disease pressure was also prominent, ranked fourth (mean = 2.36). Cowpea is highly susceptible to insect pests such as *Maruca vitrata*, aphids, and pod borers, which can cause yield losses of up to 80% if unmanaged. Despite the availability of improved pest-resistant varieties and integrated pest management (IPM) strategies, adoption remains limited due to cost and knowledge gaps. Ajeigbe et al. [5] emphasized that effective pest control is central to unlocking cowpea’s yield potential in sub-Saharan Africa. Inadequate access to credit or capital and poor market information were jointly ranked fifth (mean = 2.25 each). Access to finance is vital for the timely procurement of seeds, fertilizer, and agrochemicals, yet many smallholders are excluded from formal credit systems due to a lack of collateral or poor financial literacy. Similarly, a lack of real-time market information reduces bargaining power, weakens farm-gate prices, and prevents strategic marketing decisions. These findings are in line with Ogundari [10], who observed that financial and informational constraints significantly suppress efficiency among Nigerian smallholders.

The shortage of labor (mean = 2.19) reflects broader demographic and migration dynamics in rural areas, where able-bodied youth often migrate to urban centers, leaving behind an aging farming population. Labor shortages are particularly critical during peak farming operations, such as planting and harvesting. As reported by Saka et al. [19], such shortages contribute to delays and inefficiencies in crop production, particularly in labour-intensive systems like cowpea. Institutional challenges, such as inadequate government support (mean = 2.07) and the high cost of agrochemicals (also 2.07), were ranked eighth. These findings highlight farmers’ perceived lack of policy support, subsidies, and input delivery mechanisms. Without supportive institutions, smallholders are left vulnerable to market and environmental shocks, as noted by Issoufa et al. [6]. Finally, lack of modern equipment (mean = 2.02) and input unavailability (mean = 2.01) were the least-ranked constraints, although still relevant. The limited availability of tractors, shellers, and planters constrains mechanization and reduces labor efficiency. Meanwhile, poor input supply systems contribute to seasonal shortages or inflated input prices, further compounding production costs and inefficiencies.

4. Conclusion and practical implications

This study examined the resource use efficiency and profitability of cowpea-based farming systems in Ondo State, Nigeria, employing descriptive statistics, gross margin analysis, and a Cobb-Douglas production function model estimated via

Ordinary Least Squares (OLS). The analysis provided robust insights into the socio-economic characteristics of cowpea farmers, input utilization patterns, cost structures, and the economic viability of cowpea production, as well as the key constraints limiting productivity. The findings revealed that cowpea production is economically viable, with an impressive return on investment (ROI) of 4.26, indicating that for every ₦1 invested, farmers earn ₦4.26 in return. This high profitability confirms cowpea's potential as both a food security crop and a significant income source for smallholder farmers. However, the production process remains predominantly dependent on variable inputs, particularly labor, which accounted for the highest share of total production costs. Interestingly, the analysis also revealed that labor input was overutilized, as indicated by a negative marginal physical product (MPP) and a Marginal Value Product (MVP)/Marginal Factor Cost (MFC) ratio of less than one, highlighting inefficiencies in its application. Conversely, inputs such as farm size, agrochemicals, cowpea seed, and fertilizer were found to be underutilized, suggesting untapped potential for increasing output through a more efficient allocation of resources.

The regression analysis confirmed the significant and positive influence of farm size, fertilizer, cowpea seed, and agrochemicals on cowpea output, while labor had a statistically significant but negative effect. The model also revealed decreasing returns to scale, implying that indiscriminate scaling of input use will not yield proportional increases in output. This underscores the need for optimal input combinations, improved extension support, and knowledge dissemination to guide efficient resource allocation. Moreover, the constraint analysis identified high transportation costs, unstable output prices, environmental hazards, pest and disease incidence, and limited access to credit and market information as the most critical challenges facing cowpea producers. These challenges reflect structural weaknesses in rural infrastructure, market systems, and institutional support, which ultimately hinder the realization of cowpea's full agronomic and economic potential.

From a policy and development perspective, the findings of this study offer several key implications. Extension programs should focus on training farmers in optimal input use, particularly in addressing labor inefficiencies and promoting better use of fertilizer, improved seed varieties, and pest management strategies. Also, policy measures that facilitate access to arable land—such as land leasing schemes, land banking, or farmer cooperatives—could help address the underutilization of farm size and enhance scale efficiency. Investment in rural road networks and affordable transportation services is crucial to reduce high logistics costs and improve market access for cowpea farmers. Establishing structured cowpea markets, improving market information systems, and promoting value chain integration will help stabilize prices and improve profitability. Strengthening rural financial systems and introducing input credit schemes or subsidies can improve farmers' ability to procure quality inputs and invest in productivity-enhancing technologies. Given the significant impact of environmental hazards, promoting drought-tolerant cowpea varieties and sustainable farming practices will be essential for climate resilience. Overall, enhancing resource use efficiency, reducing production constraints, and supporting enabling environments through infrastructure, policy, and institutional reforms are central to unlocking the full potential of cowpea-based farming systems in Nigeria. Also, development interventions should not only aim at improving productivity but also safeguard employment opportunities and environmental quality, ensuring a balanced approach that supports small-scale farmers. By targeting both economic and technical inefficiencies, development stakeholders can improve the livelihoods of smallholder farmers while promoting food security and rural economic development.

Institutional review board statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of The Federal University of Technology, Akure, Nigeria, with protocol code FUTA/SAAT/ARE/25/027 on 21/07/2024.

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