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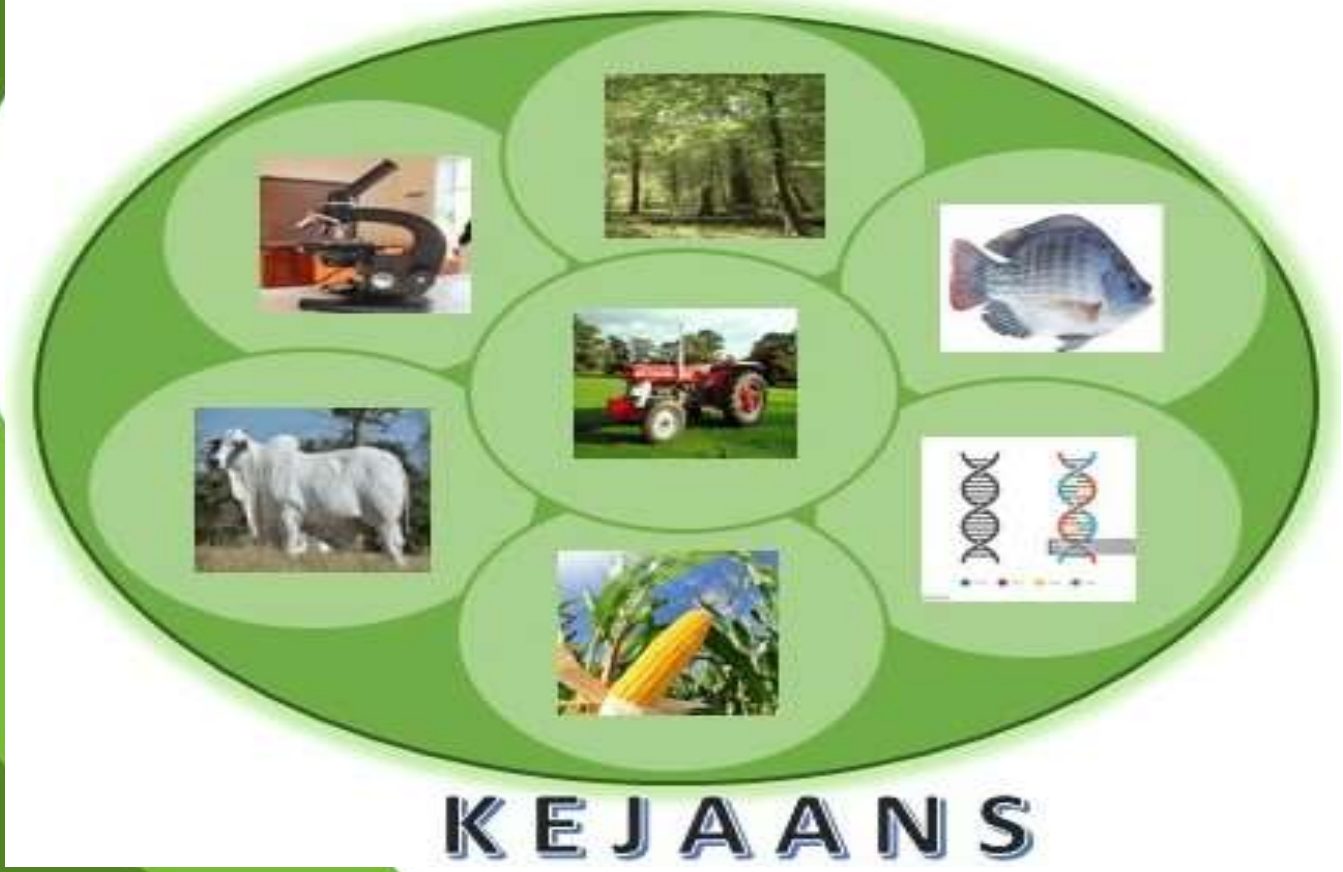

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About the Journal

This official scientific publication of the Faculty of Agriculture, Abdullahi Fodio University of Science and Technology Aliero, is a non-profit, open access, double-blind peer-reviewed Journal publishing four issues (January, April, July and October) per annum. The Journal is a platform open to collaborations with researchers, authors, institutions, research agencies and private companies related to Agriculture. The Mission of the Journal is to disseminate scientific knowledge through the publication of original research articles, research notes, book reviews, letters to the editor and reviews of Literature, representing a contribution to scientific and technological knowledge in respective areas covered by the Journal. The Kebbi Journal of Agriculture and Natural Sciences seeks to validate and disseminate new knowledge, making it public in order to strengthen the human capacity, constitute a link in the scientific community to the society and encouraging the expansion of University and academic researches.

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The Kebbi Journal of Agriculture and Natural Sciences has the sole aim of providing an intellectual platform and ideas for scholars, by promoting interdisciplinary studies related to agriculture and natural science through publishing the latest scientific research findings that are of direct policy implications and beneficial to the research community. Consequently, the journal covers all aspects of Crop Science, Animal Science, Agricultural Economics, Agricultural Extension and Rural Development, Food Science, Fisheries and Aquaculture, Biotechnology, Soil Science and Agricultural Engineering, Forestry and Environment, Wildlife, Agricultural Education, Agro-allied Industries as well as all Natural Science researches related to Agriculture.

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
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COMPARATIVE ANALYSIS OF PRODUCTION AND COST EFFICIENCY AMONG RICE FARMERS UNDER THE FADAMA III PROGRAMME IN KEBBI STATE, NIGERIA

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ABSTRACT

This study compares the production and cost efficiency of rice farmers participating in the Fadama III Programme (beneficiaries) versus non-beneficiaries in Kebbi State, Nigeria. Using a multistage random sampling technique, 500 farmers (250 beneficiaries and 250 non-beneficiaries) were selected across 11 Local Government Areas. Primary data were collected via structured questionnaires and analyzed through descriptive statistics and stochastic frontier production and cost function models. Results show that beneficiaries generally achieved higher technical, allocative, and economic efficiency. Specifically, 54.8% of beneficiaries had technical efficiency (TE) in the 0.81–0.90 range, and 38.8% exceeded 0.90; among non-beneficiaries, 64.8% were in the 0.81–0.90 band while 18.8% scored below 0.50. In the production model, farm size ($\beta = 0.1272$; $p < .01$) and labour ($\beta = 0.0449$; $p < .05$) significantly increased output among beneficiaries; agrochemical use ($\beta = 0.0315$; $p < .05$) also boosted productivity. Inefficiency declined with household size ($\beta = –0.1506$; $p < .01$) and extension contact ($\beta = –0.0614$; $p < .01$). In the cost model, farm size reduced unit costs for beneficiaries ($\beta = –0.0724$; $p < .01$), while non-beneficiaries faced higher fertilizer ($\beta = 0.1748$; $p < .01$) and labour ($\beta = 0.7796$; $p < .01$) costs. Access to credit reduced inefficiency ($\beta = –0.7751$; $p < .01$). Sigma-square and gamma diagnostics confirmed greater inefficiency among non-beneficiaries. The study concludes that Fadama III participation enhances resource use and cost efficiency. It recommends scaling up farmer training, improving credit access, and expanding input support to reduce efficiency gaps.

Keywords**:** production efficiency, cost efficiency, Fadama III, rice farmers, resource allocation

Introduction

Agriculture remains central to Nigeria's economy, especially in the northern states where the sector supports livelihoods, food security, and rural incomes. Kebbi State, located in northwest Nigeria, is a major rice-producing region due to its fertile floodplains and irrigated schemes. Yet many smallholder farmers in Kebbi face constraints such as small farm sizes, poorly maintained infrastructure, low input usage, and limited extension support (Oyebode & Akinbile, 2021; Touch *et al*., 2024). These constraints hinder efficiency and productivity, leaving many farmers below optimal performance levels.

The Fadama III Project, backed by the World Bank, was implemented to address these structural challenges by providing farmers

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

with improved access to credit, inputs, capacity building, and extension services. While evidence suggests that Fadama-type interventions raise yields and incomes in many states, the comparative **efficiency impact**—i.e. how beneficiaries differ from non-beneficiaries in terms of **input utilization and cost minimization**—is underexplored (Stanley & Mulugeta, 2022; Bello *et al*., 2023). In Kebbi, rice farmers still operate with inefficiencies in water use, input allocation, and post-harvest losses (Audu & Adie, 2018; Musa *et al*., 2024). Furthermore, environmental pressures such as desertification and climate variability impose additional uncertainty on production.

This paper addresses this gap by conducting a **comparative analysis** of **production (technical) and cost (allocative)** efficiency among rice farmers under Fadama III in Kebbi State. Using stochastic frontier methods, the study estimates efficiency scores, identifies determinants of inefficiency, and contrasts results for beneficiaries and non-beneficiaries. The findings aim to inform policy adjustments to strengthen efficiency gains, improve competitiveness, and promote sustainable agricultural interventions in Nigeria.

Methodology

Study Area

The research was carried out across Kebbi State, in the Sahel savannah zone, between latitudes 10° and 14°N and longitudes 3° and 7°E (Maikasuwa *et al*., 2023). Bounded to the west by Niger and Benin, northeast by Sokoto and Zamfara, and south by Niger State. Kebbi covers about 36,229 km² and has a population estimated at 5.66 million (NBS, 2015). The state's fertile Fadama floodplains—fed by the Niger, Rima, and Ka rivers—support both rain-fed and irrigated cropping. Rice is a major cultivated crop during the dry season along floodplains, contributing significantly to the state's economy and food security. Agriculture is the backbone of Kebbi's economy, supported by the fertile **Fadama floodplains** of the **Niger, Rima, and Ka Rivers** and their tributaries. The state's **alluvial soils** enable both **rain-fed and irrigated farming**, with major crops including **millet, maize, sorghum, cowpea, groundnut, and fonio** during the rainy season, and **rice, tomatoes, onions, peppers, and vegetables** cultivated under irrigation during the dry season.

Sampling and Sample Size

A **multistage random sampling** method was employed. The state is divided into four ADP zones; from these, **11 LGAs** were randomly selected (4 from Zone I, 3 from Zone II, 2 each from Zones III & IV). Next, **14 Fadama Community Associations (FCAs)** were chosen per LGA, followed by **83 Fadama User Groups (FUGs)**. Within these, **250 beneficiary farmers** were randomly selected. An equal number of **250 non-beneficiaries** (from neighbouring areas with similar socioeconomic and climatic settings) were also selected, giving a total sample size of **500 rice farmers**.

Data Collection

Primary data were collected using a pre-tested structured questionnaire administered over a two-month period by trained enumerators. The instrument captured information on socioeconomic attributes, input use (land, seed, fertilizer, labour, agrochemicals), output, cost components, and institutional variables (credit access, extension contacts, irrigation hours).

Analytical Framework

Descriptive statistics (mean, percentages) characterized sample attributes. The

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

stochastic frontier production function (Cobb-Douglas form) estimated technical efficiency scores, while an **inefficiency effects model** linked farm- and farmer-level variables to inefficiency. The **stochastic cost frontier** (also Cobb-Douglas) was applied to assess allocative (cost) efficiency, with inefficiency modeled similarly. The models incorporate a random error term to account for stochastic shocks (e.g. weather, price fluctuations).

Functional form:

Production model:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \ldots + \beta_k \ln X_{ki} + v_i - u_i$$

Inefficiency model:

$$u_i = \delta_0 + \delta_1 Z_{1i} + \ldots + \delta_m Z_{mi}$$

Cost model:

$$\ln C_i = \alpha_0 + \alpha_1 \ln P_{1i} + \ldots + \alpha_k \ln P_{ki} + w_i + u_i$$

Where: Y = output, X = input vector (farm size, labour, seed, fertilizer, agrochemicals), C = cost, P = input prices, Z = inefficiency determinants (age, household size, extension, credit, experience, irrigation).

Maximum likelihood estimation was used to jointly estimate coefficients and inefficiencies.

Results and Discussion

Socioeconomic Profile

Table 1 presentes the socioeconomic characteristics of the beneficiary and non-beneficiary farmers The study area is markedly male-dominated, with 84.8% of beneficiaries and 91.6% of non-beneficiaries being male—an outcome consistent with gender norms and land ownership patterns in northern Nigeria, where men largely control access to farmland and agricultural resources (Adewumi *et al*., 2021; NBS, 2023). The majority of farmers fall within the economically active age range of 28–49 years, representing 62% of beneficiaries and 58% of non-beneficiaries, with mean ages of 45.73 and 43.02 years, respectively. This suggests that the Fadama III programme has effectively engaged a productive age cohort capable of adopting and implementing improved farming practices (Ogunniyi & Ojediran, 2020). Marital status further reflects social stability in the farming population—89% of beneficiaries and 83.6% of non-beneficiaries were married, aligning with findings that household-based farming systems dominate rural economies (FAO, 2022).

Mean household sizes were 6.02 among beneficiaries and 5.48 among non-beneficiaries, indicating a reliance on family labour—a hallmark of smallholder agriculture across northern Nigeria (Adewale *et al.*, 2020). Farming remains the primary occupation for over 80% of respondents, underscoring agriculture's role as the principal livelihood source. Educational attainment, however, reveals a clear advantage among Fadama III beneficiaries: 62% reported formal education compared to 38% of non-beneficiaries, with the remainder primarily exposed to Quranic schooling. This literacy gap may partly explain the higher adoption of innovations and better record-keeping among beneficiaries (Ibrahim *et al*., 2022). Furthermore, average farm sizes were 1.86 ha for beneficiaries and 1.21 ha for non-beneficiaries—both within the smallholder range but indicative of slightly greater access to land resources among Fadama participants. Collectively, these socio-economic distinctions suggest that beneficiaries possess better endowments—education, land, and labour—that enhance their capacity to access credit, adopt improved technologies, and manage farms more efficiently than non-beneficiaries (Adenegan & Adeoye, 2023; NBS, 2023).

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

Table 1: Socioeconomic characteristics of the beneficiary and non-beneficiary farmers

	Beneficiary		**Non-Beneficiary**	
Variables	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Sex				
Male	212	84.8	229	91.6
Female	38	15.2	21	8.4
Age				
17-27	6	2.4	14	5.6
28-38	52	20.8	62	24.8
39-49	103	41.2	107	32.8
50-60	75	30.0	61	24.4
≥ 61	14	5.6	6	12.4
Mean	45.73		43.02	
Marital status				
Married	222	89	209	83.6
Single	20	8	37	14.8
Divorced	4	1	2	0.8
Widow	5	2	2	0.8
Household size				
1 – 5	139	56	139	56
6 -10	88	35	95	38
11 – 15	16	6	12	4.8
≥ 15	7	3	4	1.6
Mean	6.02		5.48	
Major occupation				
Farming	202	81	199	80
Rearing	4	1.6	3	1.2
Agro-processing	5	2.0	19	7.6
Trading	6	2.4	13	5.2
Artisan	1	0.4	1	0.4
Others	29	11.6	1	0.4

Table !..... continued

Education				
No Education	4	2	35	14.0
Adult Education	7	3	8	3.2
Primary Education	32	13	13	5.2
Secondary Education	88	35	59	23.6
Tertiary Education	35	14	22	9.0
Quranic Education	84	33	113	45
Farm size				
≤ 0. 59	48	19.2	47	18.8
0.60 – 1.59	136	54.4	145	58.0
1.60 –2.59	30	12.0	37	14.8
2.60 – 3.59	26	10.4	14	5.6
≥ 3.60	10	4.0	7	2.8
Mean	1.86		1.21	

Source: Field Survey, 2016

Technical Efficiency: Production Frontier Estimates

Results in Table 2 shows the maximum likelihood estimates of stochastic production function (Technical efficiency and Inefficiency) for rice enterprise.

The efficiency analysis indicates significant disparities between Fadama III beneficiaries and non-beneficiaries. The sigma-squared estimates (0.0932 for beneficiaries, 0.2912 for non-beneficiaries, and 0.4352 pooled) show that non-beneficiaries experience higher variability in inefficiency, while the high gamma values (0.726–0.825) confirm that most output deviations stem from inefficiency rather than random shocks. Farm size was consistently positive and highly significant across models, reaffirming the productivity advantages of scale, particularly for non-beneficiaries ($\beta = 0.5197$; $p < 0.01$). Labour and agrochemical use also contributed positively to output among beneficiaries, reflecting their importance in smallholder intensification. In contrast, the inefficiency model revealed that larger households and regular extension contact substantially reduced inefficiency, emphasizing the roles of family labour and knowledge access. Farming experience likewise enhanced efficiency through learning effects. These findings align with prior studies in Nigeria and sub-Saharan Africa, which highlight that farm size, education, labour, and extension access are pivotal determinants of production efficiency (Adenegan & Adeoye, 2023; Akinola et al., 2022; Ojo & Mohammed, 2021; FAO, 2022). Overall, the results underscore that while Fadama III has improved efficiency among beneficiaries, persistent inefficiency among non-beneficiaries signals a need for more inclusive support and sustained capacity development.

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KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

Table 2: Maximum likelihood estimates of stochastic production function (Technical efficiency and Inefficiency) for rice enterprise

	Beneficiary		Non-Beneficiary		Pooled	
Variables	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Production Model						
Constant	9.3431***	9.97	8.9032***	12.00	9.0692***	4.25
Farm size	0.1272***	4.20	0.5197***	5.87	0.2607***	7.57
Seeds	0.0123	1.16	0.0243*	1.84	0.0402***	3.93
Inorganic fertilizer	-0.0139	-0.79	0.0162	0.13	-0.0797***	-4.15
Organic fertilizer	0.0055	0.31	-0.2721***	-4.47	-0.0195	-1.01
Labour	0.0449**	2.51	0.0305	0.64	-0.0544***	-2.78
Agrochemicals	0.0315**	2.12	0.0237	0.97	-0.0182	-1.22
Inefficiency Model						
Constant	5.8154	1.56	5.4517	1.59	3.0668	1.45
Age	0.0133	0.91	-0.0878**	-2.27	-0.1062**	-2.17
Sex	0.0325	0.05	1.4007	0.26	3.9201	1.33
Household size	-0.1506***	-3.37	-0.0180	-0.12	-0.1063	-0.62
Education	0.0252	1.40	-0.0299	-0.70	0.0832	1.45
Extension contact	-0.0614***	-7.30	-0.6079	-0.87	-0.3256	-0.67
Access to credit	-0.6703	-0.96	2.0868*	1.75	1.4979	1.42
Farming experience	-0.0117	-1.09	0.0656*	1.89	0.0215***	4.90
Irrigation hour	-0.00007	-0.13	-0.0041	-1.47	-0.0035	-1.54
Diagnostic statistics						
Sigma square	0.0932**	2.37	0.2912***	9.52	0.4352***	18.38
Gamma	0.726***	9.24	0.825***	11.65	0.795***	7.23
Log-likelihood	-177.3472		-142.5989		183.4430	
N	250		250		500	

Source: Field Survey, 2016 ***P< 0.01, **p< 0.05, *p< 0.1

Cost Efficiency: Allocative Efficiency and Cost Function

Results in Table 3 presents the maximum likelihood estimates of stochastic cost function (allocative efficiency and inefficiency) for rice enterprise. The cost frontier analysis revealed substantial cost inefficiencies among rice farmers in Kebbi State, particularly non-beneficiaries of the Fadama III programme. High and significant sigma-squared and gamma values indicate that most deviations from minimum cost levels arise from inefficiency rather than random shocks (Afolabi *et al*., 2023; Ayinde *et al*., 2022). Beneficiary farmers displayed better cost management, as larger farm sizes reduced production costs through economies of scale, aligning with findings by Olayemi and Oluwatayo (2021) that larger holdings enhance cost efficiency. Conversely, non-beneficiaries

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

bore higher expenses for fertilizer and labour—inputs previously identified as key cost drivers in Nigerian rice systems (Ogunniyi et al., 2022). Organic fertilizer use significantly improved cost efficiency, corroborating studies emphasizing the economic and environmental benefits of organic amendments (Oladimeji & Abubakar, 2023).

Table 3: Maximum likelihood estimates of stochastic cost function (allocative efficiency and inefficiency) for rice enterprise

	Beneficiary		Non-Beneficiary		Pooled	
Variables	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
Cost Model						
Constant	12.9120	10.89	1.2656***	3.64	12.6657***	3.99
Cost on farm size	-0.0724	-3.85	0.0037	1.12	-0.0480***	-3.35
Cost on seeds	-0.0044	-0.64	0.0010	0.94	-0.0025	-0.52
Cost on inorganic fertilizer	0.0678	5.63	0.1748***	7.20	0.0469***	4.73
Cost on organic fertilizer	-0.0006	-0.11	0.0037***	3.35	0.0043	1.02
Cost on labour	0.2372	15.29	0.7796***	9.86	0.2432*	1.88
Cost on agrochemicals	-0.0029	-0.26	-0.0014	-0.76	0.0041	0.55
Inefficiency Model						
Constant	6.3541***	4.30	2.6561***	12.44	4.4364**	2.18
Age	0.0112	0.36	0.1563***	11.07	0.0203	0.69
Sex	7.7098***	3.35	-2.9209	-0.85	8.2284***	4.63
Household size	-0.4597**	-2.49	-0.2778	-0.49	-0.4889***	-2.75
Education	0.0286	0.64	0.1021	0.73	0.0216	0.51
Extension contact	-0.2801	-1.26	0.3081	0.60	-0.1531	-0.74
Access to credit	-0.7751***	-4.30	-1.9609	-0.08	0.2718	0.22
Farming experience	-0.0323	-1.05	-0.0150	-0.18	-0.0485	-1.48
Irrigation hour	-0.0021	-1.36	0.0961***	12.08	-0.0023*	-1.66
Diagnostic statistics						
Sigma square	0.5016***	14.96	0.6429***	15.74	0.4901***	21.56
Gamma	0.882***	11.70	0.823***	9.17	0.752***	12.12
Log-likelihood	-125.0671		-166.6255		-210.4558	
N	250		250		500	

Source: Field Survey, 2016 (***P< 0.01, **p< 0.05, *p< 0.1)

Socio-economic determinants also shaped efficiency outcomes: age and longer irrigation duration increased inefficiency, while male-headed households, access to credit, and larger family labour pools reduced it (Ibrahim *et al*., 2024; Tanko *et al*., 2023). This pattern underscores the pivotal role of financial inclusion and labour availability in lowering production costs. Overall, cost inefficiency remains a key barrier to productivity growth, but Fadama III beneficiaries demonstrated superior cost control, resource optimization, and resilience compared to non-beneficiaries—echoing evidence that targeted agricultural programmes enhance farmers'

September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

allocative and technical performance (Nwosu *et al*., 2023).

Efficiency Distributions of the Rice Farmers
Table 4a presents the distribution of the beneficiary and non-beneficiary rice farmers by technical, allocative and economic efficiency.

The distribution of efficiency scores (Table 4a) reveals notable disparities between Fadama III beneficiaries and non-beneficiaries, reflecting the programme's positive influence on productivity performance. In terms of **Technical Efficiency (TE)**, 54.8% of beneficiaries achieved scores between 0.81–0.90, and 38.8% exceeded 0.90, indicating proximity to the production frontier. Conversely, 64.8% of non-beneficiaries were in the 0.81–0.90 range, but a considerable 18.8% scored below 0.50, demonstrating weaker production management. The pooled data show 59.8% within the 0.81–0.90 range and 28.8% above 0.90, with only 1.4% below 0.50, suggesting that Fadama support has helped narrow efficiency gaps overall. These findings align with those of **Ogunniyi *et al.* (2022)** and **Ayinde *et al*. (2023)**, who observed that beneficiaries of agricultural programmes in Northern Nigeria typically exhibit higher TE due to access to credit, inputs, and technical training.
For **Allocative Efficiency (AE)**, 66.6% of farmers scored between 0.81–0.90, while 18.8% surpassed 0.90, and only 0.6% scored below 0.50. This implies that most farmers allocate resources efficiently but some still struggle with optimal input mix, consistent with **Afolabi *et al*. (2023)** who emphasized that limited market information and weak extension linkages often hinder allocative decisions. Regarding **Economic Efficiency (EE)**, 57.2% fell within 0.71–0.80, 7.8% exceeded 0.90, and 6% fell below 0.50, indicating that despite technical progress, maximizing profit remains constrained by high costs and volatile market prices—echoing **Tanko *et al*. (2023)** and **Olayemi and Oluwatayo (2021)**. Overall, the results reaffirm that Fadama III beneficiaries are closer to the efficiency frontier, while non-beneficiaries exhibit wider efficiency dispersion and greater resource misallocation, underscoring the continued need for capacity-building and market-oriented interventions.

Comparative Insights and Implications
Comparing beneficiary and non-beneficiary groups reveals that Fadama III participation is associated with greater efficiency in both production and cost realms. Beneficiaries are better able to exploit scale, control costs, and utilize inputs efficiently. Non-beneficiaries suffer from inefficient input combinations, high fertilizer/labour costs, and weaker access to extension and credit. The significant inefficiency components (high gamma values) imply that policy interventions may yield considerable gains in bridging efficiency gaps.

KEBBI JOURNAL OF AGRICULTURE AND NATURAL SCIENCES (KEJAANS)
September, 2025: Volume 1, Issue 2 : 438-449
p-ISSN: 1595-5776

Table 4a: Distribution of the beneficiary and non-beneficiary rice farmers by technical, allocative and economic efficiency

	Beneficiary						Non-Beneficiary					
Efficiency distribution	TE		AE		EE		TE		AE		EE	
	F	%	F	%	F	%	F	%	F	%	F	%
≤0.50	-	-	2	0.80	9	3.60	7	2.80	1	0.40	21	8.40
0.51-0.60	2	0.80	7	2.80	11	4.40	2	0.80	3	1.20	11	4.40
0.61-0.70	2	0.80	3	1.20	25	10.00	11	4.40	11	4.40	24	9.60
0.71-0.80	12	4.80	25	10.00	134	53.60	21	8.40	21	8.40	152	60.80
0.81-0.90	137	54.80	160	64.00	42	16.80	162	64.80	173	69.20	32	12.80
>0.90	97	38.80	53	21.20	29	11.60	47	18.80	41	16.40	10	4.00
Total	250	100.00					250	100.00				
Mean	0.895		0.846		0.751		0.819		0.843		0.714	
Minimum	0.537		0.247		0.180		0.195		0.482		0.115	
Maximum	0.999		1.000		1.000		0.999		1.000		1.000	

Source: Field Survey, 2016. Note: TE, AE and EE are technical, allocative and economic efficiency respectively.
F and % denotes frequency and percentages, respectively

Conclusion

The study highlights that agricultural interventions such as Fadama III have significantly enhanced the resource-use efficiency of smallholder rice farmers in Kebbi State. Beneficiary farmers demonstrated higher technical and allocative efficiency due to improved access to inputs, credit, and extension services. However, widespread inefficiencies persist—particularly in cost management and input utilization—indicating that the sector's productivity gains are yet to reach their full potential. Strengthening farmer capacity through expanded credit access, input support, and continuous extension engagement remains vital for sustaining the progress achieved under Fadama III and further improving rice production efficiency in the state.

Recommendations

The government should take a leading role in enhancing rice farmers' efficiency by implementing integrated support measures that address both financial and technical constraints. Expanding access to affordable credit and input subsidies will ease production costs, particularly for fertilizers and labour, while strengthening and broadening extension services will ensure that all farmers—beneficiaries and non-beneficiaries alike—receive consistent training on efficient input use and modern farming practices. Encouraging cooperative farming and shared mechanization will enable economies of scale, reducing individual production costs. Additionally, promoting judicious use of fertilizers and agrochemicals through integrated pest and nutrient management will enhance sustainability and efficiency. Finally, the government should institutionalize continuous monitoring and evaluation of efficiency gains using frontier models to guide adaptive policy decisions and ensure that interventions like Fadama III yield lasting productivity improvements.

Conflict of Interest Statement

The authors hereby declare **no conflict of interest** in relation to this study. There was no external funding, personal or institutional interest, or bias that influenced the design, analysis, or interpretation of the results.

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