Research Article

Indian Journal of Extension Education
Vol. 62, No. 3 (July–September), 2026, (187-195)

ISSN 0537-1996 (Print)
ISSN 2454-552X (Online)

Gender Differences in Production Efficiency and Food Security among Rice Farmers in Ebonyi State

Kelechi Henry Anyiam[1]*, Kelechi Chima Igwe[3], Cynthia Onyinyechi Obinna-Nwandikom[2], Taofeeq Ade Amusa[3], Okoronkwo Christopher Enoch[1], Ime Godswill Isaiah[1], Akanele Chori Obasi[1], Frank Nna Okoro[3], Obumneke Emmanuel Mbakaogu[2], Chinwe Nnene Obichere[4], Onyinyechi Innocentia Adjaero[1], Emmanuel Iyke Nnorom[1] and Ujunwa Miriam Olumba[1]

[1]Department of Agricultural Economics, Federal University of Technology Owerri, Imo State, Nigeria
[2]Department of Agribusiness, Federal University of Technology Owerri, Imo State, Nigeria
[3]Department of Agricultural Economics, Michael Okpara University of Agriculture Umudike, Umuahia Abia State, Nigeria
[4]Department of Agricultural Extension, Federal University of Technology Owerri, Imo State, Nigeria
*Corresponding author email id: kelechihenry20@gmail.com; ORCID ID (Kelechi Henry Anyiam): 0000-0003-3775-4714

HIGHLIGHTS

- Female swamp rice farmers recorded the highest technology gap ratio, despite. persistent technological inadequacies in rice production systems.
- Food insecurity was most severe among male swamp rice farmers, with a high proportion classified as food-insecure households.
- Allocative inefficiency contributed more to low economic performance than technical inefficiency among upland and swamp rice farmers.

ARTICLE INFO

Keywords: Agricultural extension, Food security, Gender analysis, Production efficiency, Rice farmers, Technology adoption.

https://doi.org/10.48165/IJEE.2026.62328

Citation: Anyiam, K. H., Igwe, K. C., Obinna-Nwandikom, C. O., Amusa, T. A., Enoch, O. C., Isaiah, I. G., Obasi, A. C., Okoro, F. N., Mbakaogu, O. E., Obichere, C. N., Adjaero, O. I., Nnorom, E. I., & Olumba, U. M. (2026). Gender Differences in Production Efficiency and Food Security among Rice Farmers in Ebonyi State. *Indian Journal of Extension Education*, *62*(3), 187-195. https://doi.org/10.48165/IJEE.2026.62328

Reviewed by: Dr. Fredrick Kobba (kobbafrederick@gmail.com); Dr. Adenipekun Shitu (topeshitu2020@gmail.com); Dr. Pravin Kumar Tiwari (tewaripk73@gmail.com)

ABSTRACT

The study examined gender, production efficiency, and food security among smallholder upland and swamp rice farmers in Ebonyi State, Nigeria, between January and December 2025. The study determined technical, allocative, and economic efficiencies by gender, assessed food security status, and identified technology gaps and inadequacies. A multi-stage sampling procedure selected 180 farmers comprising 72 upland and 108 swamp rice farmers. Data were analyzed using Data Envelopment Analysis, Foster-Greer-Thorbecke index, Technology Gap Ratio, and Technology Inadequacy Ratio. The results showed low technical and economic efficiencies across production systems. Mean technical efficiency under constant returns to scale was 0.337 for upland farmers, 0.616 for male swamp farmers, and 0.532 for female swamp farmers. Economic efficiency was highest among female upland farmers (0.307) and lowest among female swamp farmers (0.133). Food insecurity was most severe among male swamp farmers, with headcount ratio, depth, and severity indices of 0.852, 0.382, and 0.180, respectively. Female swamp farmers recorded the highest technology gap ratio (91.09%). The study concluded that gender disparities and technology inadequacies significantly influenced production efficiency and food security among rice farmers in Ebonyi State.

INTRODUCTION

Rice remains one of the major staple foods in Nigeria and contributes significantly to food security, employment generation, and rural livelihoods. Nigeria cultivates rice across several agro-ecological systems, particularly upland and swamp ecosystems commonly practiced in Ebonyi State, one of the leading rice-producing states in the country (FAO, 2023; Chima et al., 2024).

Received 21-05-2026; Accepted 05-06-2026

Despite favourable agro-ecological conditions for rice cultivation, productivity among smallholder rice farmers remains relatively low, estimated at about 2–3 tons per hectare across major production systems, largely due to continued reliance on traditional farming practices and low-input technologies (Kamai et al., 2020). In contrast, global average rice yields are reported at approximately 4.7 tons per hectare, with high-performing production systems exceeding 6 tons per hectare (FAO, 2024). This difference highlights a persistent and substantial yield gap between smallholder rice farmers and global productivity benchmarks.

Improving production efficiency among rice farmers remains critical because inefficient utilization of productive resources limits output and farm profitability. Smallholder farmers in Ebonyi State often experience inadequate access to improved seeds, fertilizers, mechanization, credit facilities, and extension services, thereby reducing their capacity to optimize production resources (Ezeh et al., 2022). Weak extension support and poor dissemination of improved rice technologies further constrain technology adoption and resource-use efficiency among rural farming households (Silva, 2023; Chandra et al., 2023).

Food security among rice farming households is strongly influenced by gender roles and access to productive resources. Male and female farmers differ in labour participation, access to extension information, credit facilities, land ownership, and innovation platforms, thereby affecting production efficiency and household welfare outcomes (Ezeaputa et al., 2020). Women are more actively involved in planting, processing, and marketing activities, while men dominate land preparation and harvesting operations. Gender disparities in access to agricultural information and extension services continue to influence technology adoption and productivity among smallholder farmers (Silva, 2023).

Agricultural extension services play an important role in improving farmers' technical knowledge, strengthening innovation dissemination, and promoting climate-smart agricultural practices. Effective extension delivery systems enhance farmers' ability to adopt improved production technologies and efficiently utilize available production resources. Recent studies emphasize that extension interactions, ICT utilization, and farmer information networks significantly improve agricultural technology adoption and farm productivity (Nain et al., 2015; Gogoi et al., 2022; Niranjan et al., 2023; Chandra et al., 2023). Strengthening gender-responsive extension systems may therefore improve production efficiency and food security among rice farmers.

Although previous studies examine production efficiency, food security, and gender issues separately, limited empirical evidence exists on how gender disparities, extension-related factors, technology gaps, and production systems jointly influence production efficiency and food security among upland and swamp rice farmers in Ebonyi State (Aryal et al., 2019; Munonye et al., 2023). This study therefore examines the technical, allocative, and economic efficiencies of upland and swamp rice farmers by gender, assesses the food security status of rice farming households, and identifies technology gaps among rice farmers in Ebonyi State, Nigeria.

METHODOLOGY

This study was conducted in Ebonyi State, Nigeria, one of the major rice-producing states in southeastern Nigeria. The state was divided into three agricultural zones: Ebonyi North, Ebonyi Central, and Ebonyi South. Ebonyi State had an estimated population of about 2.9 million people in 2016 (National Population Commission [NPC], 2016) and occupied a land area of approximately 5,935 km² (Nwahia et al., 2020). Agriculture constituted the major occupation of the residents, with most rural households engaged in crop production activities. The state experienced a humid tropical climate characterized by high rainfall and favourable environmental conditions suitable for rice cultivation (Onyeneke, 2021). Major food crops cultivated in the area included rice, cassava, yams, and vegetables. Rice production in Ebonyi State was practiced under upland and swamp production systems. Upland rice farming was concentrated mainly in Izzi and Ikwo Local Government Areas (LGAs), while swamp rice cultivation was predominant in Ohaozara and other lowland areas (Chidiebere-Mark et al., 2019). The soils in the state were predominantly loamy and clayey, making them suitable for rice production. A multi-stage sampling procedure involving five stages was used for respondent selection. In the first stage, three LGAs namely Izzi, Ikwo, and Ohaozara were purposively selected based on the intensity of rice production. In the second stage, three communities were randomly selected from each LGA, resulting in nine communities. The third stage involved the random selection of two villages from each community, giving a total of eighteen villages. In the fourth stage, rice farmers were stratified into upland and swamp rice farmers and further categorized into male upland, female upland, male swamp, and female swamp farmers. In the fifth stage, proportionate random sampling was used to select respondents from the sampling frame obtained during the pre-survey exercise. A total of 180 rice farmers were selected for the study, comprising 72 upland rice farmers (36 males and 36 females) and 108 swamp rice farmers (54 males and 54 females). Primary data were collected using structured questionnaires and interview schedules. Data collected were cross-sectional in nature and were analysed using descriptive and inferential statistics. The Cobb-Douglas production function was used to estimate technical, allocative, and economic efficiencies among rice farmers. Extension-related variables such as access to extension services, adoption of improved rice technologies, and participation in advisory activities were also considered because of their influence on technology adoption and efficient resource utilization among smallholder farmers. Gender analysis was conducted using descriptive statistics, including frequencies, percentages, and mean comparisons. Variables examined included access to agricultural extension services, improved seed utilization, fertilizer application, agricultural credit, farm size, and technology adoption. These indicators were compared across male and female rice farmers within upland and swamp production systems to identify gender-based disparities in access to productive resources and agricultural support services.

Data Envelopment Analysis (DEA) VRS output-oriented model used by Kohl et al. (2019) and Ismail et al. (2018) was adopted for this study.

Technical efficiency refers to the ability of a DMU to obtain maximum output from a given set of inputs. An input-oriented DEA model was used to assess how much input quantities were proportionally reduced without changing the output quantities. The choice of DEA in this research study is that it does not assume a specific production function and does not introduce any statistical noise. The model is specified as follows:

Minimize θ
Subject to:
$\Sigma\lambda_j X\{ij\} \leq \theta nx\{nj\}$, for all inputs i … Equation (1)
$\Sigma\lambda j Y\{ij\} \geq Y\{nj\}$, for all outputs i
$\lambda j \geq 0$, for all j

Where, Xij is the quantity of inputs (i) used by the j farmers, the inputs are the farm size (Ha), labour (man-hour), capital investment (naira), fertilizer (kg), agrochemicals (litres), rice grain (kg), Y_{ij} = quantity of output (i) produced by j farmers, λj = non-negative weights assigned to each DMU, θ = efficiency score (θ ≤ θ ≤ 1), n = number of DMU

Technical efficiency was computed, and allocative efficiency was derived by comparing the cost-minimizing input combination to the technically efficient input usage. The EE score for a given field n was obtained by first solving the following cost-minimizing LP model:

$MC_n = \min_{\lambda xij} \ \Sigma^I_{i=1} PnjXnj$ ... Equation (2)
Subject to $\Sigma^I_{i=1}\lambda iXij - Xnj \leq 0$
$\Sigma^I_{i=1}\lambda iYik - Xnk \geq 0$
$\Sigma^I_{i=1}\lambda_I = 1$
$\lambda_i \geq 0$

Where, MC_n = the minimum total cost for field *n; Pnj* = the price for input *j* on the field *n*; and X^*nj = the cost-minimizing the level of input *j* on field n given its input price and output levels. All other variables in equation 2.6 are as defined previously. The constraints $\Sigma^I_{i=1}\lambda_I = 1$ ensures that the minimum total costs for the field are calculated under the VRS assumption. Economic efficiency (EE_n) for each field is then calculated using the following equation:

$$EE_n = \frac{\Sigma^I_{i=1}PnjXnj}{\Sigma^I_{i=1}PnjXnj} \quad \text{... Equation (3)}$$

Where the numerator $\Sigma^I_{i=1}PnjXnj$ = the minimum total cost obtained for field n using equation (3.3) and the denominator $\Sigma^I_{i=1}PnjXnj$ = the actual total cost observed for field n. The EE_n for a given field takes on a value ≤ 1; with an EEn = 1 indicating the field is economically efficient and EEn < 1 indicating the field is economically inefficient. The EE for a DMU can also be represented as the product of both the TE and AE for the DMU or EEn = TEn x AEn (Farrell, 1957).

$$AE = \frac{EE}{TE} \quad \text{… Equation (4)}$$

AE will be ≤ 1, with AE = 1, meaning efficient allocation of resources and AE < 1, meaning allocative inefficient.

To assess the effect of gender on efficiency, the DEA efficiency scores (TE and AE) were regressed against gender, age, farm size, farming experience, household size, and rice production system using a binary logistic regression model. This allowed for a statistical test whether gender significantly affects efficiency levels.

Foster-Greer-Thorbecke (FGT) decomposable indices as used by Amusan et al. (2023). The model is specified as follows;

$$P_a = \frac{1}{n}\sum\left(\frac{Z-Y_i}{Z}\right)^a \text{ x I } (Y_i < Z) \quad \text{... Equation (5)}$$

Where, I (Y_i < Z) = is a food security indicator function that takes the value of 1(food secured) if Yi > Z, and 0 (food insecure) if Yi < Z, Z = Minimum calorie requirements per day per adult equivalent (kcal), Y_i = Average monthly expenditure of the individual farmers (~~N~~), α = is a non-negative parameter that takes the value of zero (0) for the headcount ratio, 1 for the food insecurity gap index, and 2 for the squared food insecurity gap index, n = Total sample size

The headcount ratio (HCR) is expressed as;

$$HCR = \frac{N}{n} \quad \text{… Equation (6)}$$

Where, N = Number of farmers living below the recommended minimum calorie requirement per day; n = sample size

$$\text{Food Insecurity Gap Index (ij)} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{Z-C}{Z}\right) \quad \text{... Equation (7)}$$

Where, q_{ij} = Number of food-insecure households (households for food consumption C < Z), Z_{ij} = food secured threshold (2,250 kg/day), C_{ij} = food consumption level (expenditure on food) of the i^{th} food-insecure household, i = i^{th} household by gender, j = j^{th} production system.

The study adopted the model used by Dossou-Yovo et al. (2020) to find out Technology Gap Ratio. The model was expressed as follows:

$$TGR_{ji} = \frac{\text{Actual Rice Yield (kg)}}{\text{Potential Yield (kg)}} \text{ x 100} \quad \text{… Equation (8)}$$

Where, TGR = Technology Gap Ratio

Actual yield is the quantity of rice (upland and swamp rice) tons/ha that a farmer harvests from their field under current practices and conditions. Potential yield is the maximum possible yield of (upland and swamp rice) tons/ha that can be achieved under optimal conditions no limitations from pests, water, or nutrients, and using the best management practices for a given rice variety and environment.

According to Kamai et al. (2020) potential yield for upland rice is between 4.0 to 6.0 tons/ha under optimal conditions using the best farm management practices, while the potential yield for swamp rice is between 6.2 to 8.0 tons/ha under optimal conditions using the best farm management practices.

If TGR = 50%, it means a moderate gap/partial gap in technology, If TGR < 50%, it means a high gap/wide gap in technology and If TGR > 50%, it implies a low gap/closing the technology gap.

$$\text{Technology Inadequacy Ratio} = 1 - \frac{\text{No. of Technology Adopted}}{\text{Total No. of Technology Considered}} \quad \text{…Equation (9)}$$

The eight essential components of rice production technology were considered. They include improved seeds, use of chemical fertilizers, agrochemical use, machine seed broadcasting, irrigation, machine seed transplanting, use of automated water sprinklers, and access to agricultural extension services. Each respondent received a binary score, where 1 indicated adoption of the technology and 0 indicated non-adoption.

If the TIR = 0, it implies that technology is adequate, the farmers have adopted all the technology, If the TIR > 0, it implies that technology is inadequate, and the farmers have not adopted all the technology.

RESULTS

The results of the level of technical, allocative and economic efficiencies by gender in upland and swamp rice production systems are presented in Tables 1 and 2.

Table 1 presents the technical and scale efficiency estimates of upland and swamp rice farmers by gender. The results showed that male and female upland rice farmers recorded relatively low mean overall technical efficiency scores of 0.337, indicating that they operated substantially below the production frontier and could potentially increase output by approximately 66.3% using existing resources and available technologies. In contrast, male swamp farmers recorded the highest technical efficiency score (0.616), followed by female swamp farmers (0.532), suggesting relatively better resource utilization under swamp production systems. The generally low scale efficiency values across all farmer categories indicate that most farmers were not operating at optimal production scales. This implies that inefficiencies were attributable not only to technical limitations but also to poor scale management and suboptimal allocation of productive resources.

Table 2 presents the allocative and economic efficiency estimates of rice farmers across gender and production systems. Female upland farmers recorded the highest allocative efficiency score (0.519), while female swamp farmers recorded the lowest (0.386). Similarly, economic efficiency was highest among female upland farmers (0.285) and lowest among male swamp farmers (0.166). These findings indicate that farmers were unable to combine production inputs in cost-minimizing proportions, resulting in substantial economic inefficiencies.

Table 3 presents the food security status of rice farmers across gender and production systems. Food insecurity was most severe among male swamp farmers, with a headcount ratio of 0.852, indicating that 85.2% of households in this category were food insecure. Female swamp farmers also recorded a relatively high incidence of food insecurity (68.5%). In contrast, male and female upland farmers recorded lower food insecurity incidences of 47.2% and 55.6%, respectively. The depth and severity indices further revealed that food insecurity among swamp farmers was not only more widespread but also more intense.

Table 4 presents the technology gap ratio among rice farmers by gender and production system. Female swamp farmers recorded the highest technology gap ratio (91.09%), followed by female upland farmers (78.47%). Male upland and male swamp farmers recorded lower technology gap ratios of 47.40% and 48.96%, respectively. These findings indicate substantial differences in the utilization of available rice production technologies.

Table 5 presents the technology inadequacy ratio among rice farmers. Male and female upland farmers recorded technology inadequacy ratios of 0.44, while male and female swamp farmers recorded lower ratios of 0.22. The pooled technology inadequacy ratio was 0.33. These findings indicate that none of the farmer groups adopted all recommended rice production technologies and that important gaps remained between recommended and actual farming practices.

Table 6 presents the distribution of farmers across technology gap categories. The majority of farmers belonged to the technology gap-closing category, including 61.1% of male upland farmers, 66.7% of female upland farmers, and 63.0% of female swamp farmers. However, only 42.6% of male swamp farmers belonged to this

Table 1. Technical and scale efficiencies of upland and swamp rice farmers by gender

Indices	Male Upland			Female Upland		
	OTE (%)	PTE (%)	SE (%)	OTE (%)	PTE (%)	SE (%)
0.05 – 0.35	66.7	69.4	72.2	72.2	75.0	66.7
0.35 – 0.66	19.4	13.9	11.1	13.9	13.9	19.4
0.65 – 0.95	5.6	11.1	5.6	5.6	8.3	11.1
0.95 – 1.25	8.2	5.6	11.1	8.3	2.8	2.8
Total	100	100	100	100	100	100
Mean	0.337	0.887	0.385	0.337	0.524	0.777
Max	1.000	1.000	1.000	1.000	1.000	1.000
Min	0.051	0.288	0.051	0.035	0.041	0.074
Indices	Male Swamp			Female Swamp		
	OTE (%)	PTE (%)	SE (%)	OTE (%)	PTE (%)	SE (%)
0.18 – 0.58	46.3	46.3	44.4	44.4	42.6	48.1
0.58 – 0.98	37.0	35.2	37.0	31.5	29.6	27.8
0.98 – 1.38	16.7	18.5	18.6	24.1	27.8	24.1
Total	100	100	100	100	100	100
Mean	0.616	0.889	0.710	0.532	0.851	0.658
Max	1.000	1.000	1.000	1.000	1.000	1.000
Min	0.188	0.220	0.231	0.136	0.162	0.159

Source: Computed from Field Survey Data, 2025 MaxDEA Software Overall Technical Efficiency (OTE), Pure Technical Efficiency (PTE), Scale Efficiency (SE)

Table 2. Allocative and Economic Efficiencies of Rice Farmers by Gender

Indices	Male Upland			Female Upland		
	OAE (%)	PAE (%)	EE (%)	OAE (%)	PAE (%)	EE (%)
0.05 – 0.35	47.2	52.7	75.0	66.7	47.2	25.0
0.35 – 0.66	33.3	22.2	19.4	8.3	44.4	58.3
0.65 – 0.95	16.7	22.2	2.8	19.4	5.6	13.9
0.95 – 1.25	2.8	2.9	2.8	5.6	2.8	2.8
Total	100	100	100	100	100	100
Mean	0.507	0.177	0.285	0.519	0.198	0.307
Max	1.000	1.000	1.000	1.000	1.000	1.000
Min	0.289	0.244	0.089	0.049	0.001	0.002
Indices	Male Swamp			Female Swamp		
	OAE (%)	PAE (%)	EE (%)	OAE (%)	PAE (%)	EE (%)
0.18 – 0.58	46.3	46.3	85.2	61.1	61.1	88.9
0.58 – 0.98	50.0	48.1	11.1	33.3	31.5	5.6
0.98 – 1.38	3.7	5.6	3.7	5.6	7.4	5.6
Total	100	100	100	100	100	100
Mean	0.470	0.264	0.166	0.386	0.205	0.133
Max	1.000	1.000	1.000	0.999	0.999	0.999
Min	0.056	0.003	0.001	0.031	0.001	0.003

Source: Computed from Field Survey Data, 2025 MaxDEA Software Overall Allocative Efficiency (OAE), Pure Allocative Efficiency (PAE), Economic Efficiency (EE)

Table 3. Food Security Status of Rice Farmers by Gender

Groups	n	Food Insecure	Headcount Ratio	Extent of Insecurity	Severity of Insecurity
Male Upland	36	17	0.472	0.186	0.010
Female Upland	36	20	0.556	0.192	0.050
Male Swamp	54	46	0.852	0.382	0.180
Female Swamp	54	37	0.685	0.257	0.120
Pooled Sample	180	120	0.667	0.102	0.204

Table 4. Technology Gap Ratio among Rice Farmers

Group	Actual Yield (kg)	Potential Yield (kg)	TGR (%)	Remark
Male Upland	1263.89	2666.67	47.40	Wide gap
Female Upland	2004.17	2554.17	78.47	Closing gap
Male Swamp	781.48	1596.0	48.96	Wide gap
Female Swamp	1636.11	1796.20	91.09	Closing gap

TGR = 50% (Moderate gap), TGR > 50% (Closing gap), TGR < 50% (Wide gap)

Table 5. Technology Inadequacy among Rice Farmers by Gender

Group	NTA	TNTC	TIR = $(1 - \frac{NTA}{TNTC})$	Remark
Male Upland	5	9	0.44	Technology Inadequacy
Female Upland	5	9	0.44	Technology Inadequacy
Male Swamp	7	9	0.22	Technology Inadequacy
Female Swamp	7	9	0.22	Technology Inadequacy
Pooled Sample	24	36	0.33	Technology Inadequacy

NTA (Number of technologies adopted), TNTC (Total number of technologies considered), TIR (Technology Inadequacy Ratio)

category. Conversely, 55.5% of male swamp farmers fell within the wide-gap category. Table 7 presents the Pearson correlation analysis between technology gap ratio and technology inadequacy ratio across gender and production systems. The results revealed positive but statistically insignificant relationships among male upland farmers ($r = 0.097$; $p = 0.574$), female upland farmers ($r = 0.215$; $p = 0.207$), male swamp farmers ($r = 0.060$; $p = 0.667$), and female swamp farmers ($r = 0.196$; $p = 0.156$).

Tale 6. Technology Gap Categories among Rice Farmers by Gender in percent

Technology Gap	Male Upland	Female Upland	Male Swamp	Female Swamp
Closing Gap	61.1	66.7	42.6	63.0
Moderate Gap	2.8	5.6	1.9	1.9
Wide Gap	36.1	27.7	55.5	35.1
Total	100	100	100	100

Table 7. Pearson correlation between technology gap and technology inadequacy rations across gender and rice production systems

Group	Variables compared	Pearson's R	P – value	Interpretation	Decision @ 5%
Male Upland	TGR vs TIR	0.097	0.574	Not significant	Accepted
Female Upland	TGR vs TIR	0.215	0.207	Not significant	Accepted
Male Swamp	TGR vs TIR	0.060	0.667	Not significant	Accepted
Female Swamp	TGR vs TIR	0.196	0.156	Not significant	Accepted

TGR = Technology Gap Ratio, TIR = Technology Inadequacy Ratio.

DISCUSSION

The low efficiency levels observed among upland farmers may be linked to the inherent production challenges associated with upland rice cultivation. Upland systems depend largely on rainfall and are more susceptible to moisture stress, declining soil fertility, weed infestation, and climatic variability. These constraints reduce farmers' ability to achieve maximum output from available resources. In addition, many upland farmers rely on traditional production methods, low-input technologies, and family labour, which may limit productivity. Fragmented landholdings further constrain mechanization and efficient resource coordination, thereby reducing scale efficiency.

The relatively higher efficiency observed among swamp farmers highlights the importance of ecological suitability in rice production. Swamp ecosystems generally provide favourable water conditions and improved soil moisture, thereby supporting higher productivity. These findings agree with Gogoi et al. (2022), who reported that farmer exposure to improved production practices, extension contact, and technical knowledge significantly enhanced rice productivity and technology utilization.

Despite the higher technical efficiency of swamp farmers, persistent scale inefficiencies suggest that many farmers still fail to combine production resources optimally. Such inefficiencies may arise from limited access to land, labour shortages, inadequate financial resources, and weak managerial capacity. Ehirim et al. (2022) similarly reported that efficiency losses were strongly influenced by variations in farm size and operational scale. The findings therefore suggest that improving managerial capacity and resource coordination could substantially enhance rice productivity.

The efficiency differentials observed between male and female farmers further indicate that gender-related factors continue to influence production outcomes. Although women demonstrated comparable and, in some cases, better resource coordination, they often face greater barriers in accessing land, credit, mechanization services, improved seeds, and extension support. These constraints may limit their ability to achieve higher efficiency levels despite their active participation in rice production. The findings therefore reinforce evidence that gender disparities remain important determinants of agricultural productivity among smallholder farmers in sub-Saharan Africa.

The low allocative efficiency scores suggest that farmers faced difficulties in making optimal resource allocation decisions. Such inefficiencies may result from inadequate market information, fluctuations in input prices, limited managerial skills, and poor access to credit. Many smallholder farmers lack the financial capacity required to purchase productive inputs in economically optimal quantities. Consequently, they often rely on suboptimal input combinations that reduce profitability.

The results further show that relatively higher technical efficiency does not necessarily translate into economic efficiency. Although swamp farmers performed better technically, they recorded comparatively lower economic efficiency levels. This may be due to the higher production costs associated with swamp rice cultivation, including labour-intensive operations, water management requirements, and vulnerability to flooding. Consequently, increased output does not always correspond to higher profitability.

The findings corroborate Michael et al. (2021), who reported that inefficient allocation of production resources significantly reduced farm profitability among smallholder farmers. Similarly, Chandra et al. (2023) found that farmers' access to information and production resources played an important role in determining production outcomes. The present results therefore emphasize the need to strengthen farmers' managerial capacity, improve access to market information, and enhance agricultural financing opportunities. Such interventions would improve allocative efficiency and enable farmers to convert technical gains into improved economic performance.

These findings demonstrate that higher technical efficiency alone does not guarantee improved household food security. Although swamp farmers generally recorded better production efficiency, they remained highly vulnerable to food insecurity. This suggests that food security is influenced by several factors beyond agricultural productivity, including income stability, market access, household expenditure patterns, and exposure to production risks.

The higher food insecurity observed among swamp farmers may be associated with environmental uncertainties such as flooding, unstable yields, and crop losses. Frequent flooding can reduce harvest volumes, increase post-harvest losses, and disrupt household income streams. Such conditions may weaken household purchasing power and limit access to adequate food throughout the year. Consequently, households may remain food insecure despite participating actively in rice production.

The findings are consistent with Munonye et al. (2023) and Esheya et al. (2024), who reported widespread food insecurity among farming households in Ebonyi State. Similar studies have shown that participation in agriculture does not automatically guarantee food security because household welfare depends on broader socioeconomic conditions. The present results therefore suggest that policies aimed at improving productivity should be complemented by interventions that strengthen household resilience, diversify income sources, and improve market access.

Gender disparities also appeared to influence food security outcomes. Women often experience limited access to productive resources and income-generating opportunities, thereby increasing household vulnerability. Njoku et al. (2025) similarly reported that inequalities in access to agricultural resources significantly influenced household welfare and food security outcomes. The findings therefore underscore the importance of gender-sensitive agricultural interventions. Furthermore, limited access to extension information and climate-smart advisory services may reduce farmers' capacity to manage production risks effectively. Silva (2023) observed that stronger information networks and social learning systems improved farmers' adaptive capacity and technology adoption. Strengthening extension communication systems may therefore contribute significantly to improved food security among rice farming households.

The results suggest that female farmers were relatively more successful in translating available technologies into productive outcomes despite facing resource constraints. However, the persistence of technology gaps across all groups indicates that improved rice technologies remained underutilized. This suggests that awareness alone is insufficient to guarantee effective adoption and utilization.

Several factors may explain the observed technology gaps, including limited access to credit, inadequate technical knowledge, high input costs, and poor access to improved production inputs. Farmers who lack financial resources may be unable to adopt improved seeds, fertilizers, herbicides, and mechanized technologies required for modern rice production. Ibrahim et al. (2024) similarly reported that inadequate extension support and limited access to productive resources constrained technology adoption among rice farmers. The findings therefore suggest that improving technology utilization requires both enhanced awareness and improved access to productive resources.

The persistence of technology inadequacies suggests weaknesses in agricultural extension and innovation dissemination systems. Many farmers continue to rely on traditional production methods despite increasing awareness of improved technologies. Weak extension-farmer interaction, inadequate technical training, and limited practical demonstrations may have constrained effective adoption.

In many rural communities, extension services are challenged by inadequate staffing, poor funding, and logistical limitations. Consequently, farmers often receive insufficient technical guidance. Gogoi et al. (2022) reported that regular contact with extension agents significantly influenced rice technology adoption, while Chandra et al. (2023) found that ICT-based information platforms improved farmers' decision-making and technology utilization.

The findings have important implications for agricultural extension education. Persistent inefficiencies, food insecurity, and technology inadequacies indicate the need for stronger extension systems capable of promoting innovation dissemination, farmer learning, and climate-smart agricultural practices. Particular attention should be given to gender-responsive extension approaches that address the specific constraints faced by female farmers.

The predominance of farmers in the technology gap-closing category suggests that substantial progress has been made in narrowing technology gaps among rice farmers. This may reflect increasing awareness of improved production technologies and the positive effects of extension activities. However, the large proportion of farmers in the wide-gap category indicates that technology adoption remains uneven.

The particularly high proportion of male swamp farmers within the wide-gap category suggests the presence of significant barriers to technology utilization. These barriers may include financial constraints, inadequate technical knowledge, poor access to inputs, and environmental challenges associated with swamp rice production. The finding is consistent with the technology gap ratio results, which showed considerable variation in technology utilization across farmer groups.

The low proportion of farmers in the moderate-gap category suggests that farmers tended to cluster at either end of the adoption spectrum. Consequently, interventions should focus on farmers within the wide-gap category, where the greatest opportunities for productivity improvement exist. Strengthening farmer training, demonstration programmes, cooperative learning platforms, and ICT-enabled advisory services could accelerate movement from the wide-gap category to the technology gap-closing category.

The positive coefficients suggest that technology inadequacy tended to increase alongside technology gaps. However, the lack of statistical significance indicates that technology inadequacy alone did not explain variations in technology gaps among the farmer groups. This implies that additional factors such as managerial ability, access to extension services, environmental conditions, input quality, and financial resources may have influenced technology utilization outcomes.

The findings suggest that reducing technology gaps requires more than promoting technology adoption alone. Integrated interventions that combine technology dissemination with improved access to credit, extension support, productive inputs, and farmer training are likely to generate greater improvements in productivity, efficiency, and household welfare among rice farmers in Ebonyi State.

CONCLUSION

The study concluded that production efficiency, food security, and technology utilization differed across gender groups and rice production systems in Ebonyi State. Although swamp farmers generally recorded higher technical efficiency, food insecurity remained more pronounced among them due to ecological risks and unstable production conditions. Persistent inefficiencies in resource allocation, scale management, and technology use limited productivity and profitability among rice farmers. Gender disparities in access to land, credit, extension services, and improved technologies further influenced production outcomes and household welfare. The findings also revealed that technology inadequacies and gaps persisted because of weak extension support and limited dissemination of improved rice technologies. Therefore, improving rice productivity and food security requires gender-responsive extension services, enhanced access to credit and productive resources, farmer capacity building, and wider adoption of climate-smart technologies. Strengthening participatory and ICT-enabled advisory systems could significantly improve technology uptake, efficiency, and rural livelihoods.

DECLARATIONS

Ethics approval and informed consent: This research was conducted in accordance with established ethical standards for social science research. Verbal informed consent was obtained from all participating rice farmers before data collection. Respondents were assured of confidentiality, anonymity, and the voluntary nature of their participation throughout the study.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors further declare that they have thoroughly reviewed, revised, and edited the manuscript and take full responsibility for the final content of this publication. The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions: K.H. Anyiam = Conceptualization, methodology, supervision, manuscript drafting, data analysis, interpretation. K.C. Igwe and T.A. Amusa = Data analysis, interpretation, manuscript review. C.O. Obinna-Nwandikom = Statistical modelling, literature review. O.C. Enoch = Methodology development, editing. A.C. Obasi = Data collection, preparation of tables. F.N. Okoro = Review of related literature, referencing. O.E. Mbakaogu = Manuscript editing, formatting. I.G. Isaiah, E.I. Nnorom and C.N. Obichere = Data collection, critical revisions. U.M. Olumba and O.I. Adjaero = Policy recommendations, conclusion drafting. All authors read and approved the final manuscript.

Publisher's note: All claims expressed in this article are solely of the authors and don't necessarily represent those of their affiliated organizations. Any product/ process or technology that may be evaluated in this article, or a claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher. The Indian Journal of Extension Education remains neutral with regard to jurisdictional claims.

REFERENCES

Amusan, J. M., Dada, G. E., Adejoorin, M. V., Adewale, A. A., Salufu, O. A., Salman, K. K., & Atoyebi, J. O. (2023). Impact of climatic variability on food security among rural households in Nigeria. In Proceedings of the 22nd National Conference of the Nigerian Association of Agricultural Economists (NAAE) (pp. 68–85). University of Ibadan.

Aryal, J. P., Mottaleb, K. A., & Rahut, D. B. (2019). Untangling gender differentiated food security gaps in Bhutan: An application of exogenous switching treatment regression. *Review of Development Economics, 23*(2), 782–802. https://doi.org/10.1111/rode.12566.

Chandra, S., Singh, A. K., Ghadei, K., & Pradhan, S. (2023). Exploring the relationship between socio-economic factors and ICT adoption among farmers. *Indian Journal of Extension Education, 59*(3), 54–57. http://doi.org/10.48165/IJEE.2023.59310 .

Chidiebere-Mark, N., Ohajianya, D., Obasi, P., & Onyeagocha, S. (2019). Profitability of rice production in different production systems in Ebonyi State, Nigeria. *Open Agriculture, 4*(1), 237–246. https://doi.org/10.1515/opag-2019-0023

Chima, O. C., Genevie, D. E., Duruji, M. M., Osimen, G. U., & Abasilim, U. (2024). Anchor Borrowers' Programme on rice production and food security in Ebonyi State, Nigeria. *African Journal of Biological Sciences, 6*(13), 2378–2397. https://doi.org/10.33472/AFJBS.6.13.2024.2378-2397

Dossou-Yovo, E. R., Vandamme, E., Dieng, I., Jean-Martial, J., & Kazuki, S. (2020). Decomposing rice yield gaps into efficiency, resource, and technology yield gaps in sub-Saharan Africa. *Field Crops Research*, *258*, 107963. https://doi.org/10.1016/j.fcr.2020.107963

Esheya, S. E., Ogbonna, S. I., & Nwandu, P. I. (2024). Empirical analysis of the factors promoting food insecurity among farming households in Ebonyi State, Nigeria. *Greener Journal of Agricultural Sciences, 14*(1), 33–39. https://gjournals.org/GJAS

Ezeaputa, P. C., Onugu, U. C., Obiekwe, N. J., & Offiah, E. O. (2020). Assessment of the participation of women in family farming among rice-producing communities in rural areas of Anambra State, Nigeria. *International Journal of Applied Science and Research*, *3*(5), 133–171. https://www.ijasr.org/paper/IJASR0042261

Ezeh, A. N., Enyigwe, J. O., & Egwu, P. N. (2022). Farmers' utilization of improved rice production technologies in Ebonyi State, Nigeria. Global *Journal of Agricultural Sciences*, *21*, 43–49. https://doi.org/10.4314/gjass.v21i1.6

Food and Agriculture Organization of the United Nations (FAO). (2023). The status of women in agrifood systems. FAO. https://doi.org/10.4060/cc5343en

Food and Agriculture Organization of the United Nations (FAO). (2024). FAOSTAT statistical database: Crops and livestock products. https://www.fao.org/faostat/en/#data/QCL

Gogoi, J., Buragohain, R., & Deka, N. (2022). What motivates rice farmers to adopt hybrid rice technology in Assam, India? *Indian Journal of Extension Education, 58*(3), 74–77. https://doi.org/10.48165/IJEE.2022.58316 .

Ibrahim, R. M., Abdullahi, S., Haruna, U., & Dabo, N. M. (2024). Factors influencing the adoption of improved rice production technologies in Western Zone, Bauchi State, Nigeria. *Nigerian Journal of Agriculture and Agricultural Technology*, *4*(4A), 101–111. https://doi.org/10.59331/njaat.v4i4A.864

Ismail, A., Zahid, Z., Hussin, S. A. S., & Khairi, S. S. M. (2018). Modelling the efficiency of paddy production in Peninsular Malaysia using principal component analysis and data envelopment analysis (PCA-DEA). International Journal of Supply Chain Management, *7*(4), 158–171.

Kamai, N., Omoigui, L. O., Kamara, A. Y., & Ekeleme, F. (2020). Guide to rice production in northern Nigeria. International Institute of Tropical Agriculture. https://www.iita.org/wp-content/uploads/2020/07/Guide-to-Rice-Production-in-Northern-Nigeria

Kohl, S., Schoenfelder, J., Fugener, A., & Brunner, O. J. (2019). The use of Data Envelopment Analysis (DEA) in healthcare with a focus on hospitals. *Health Care Management Science, 22*, 423–451. https://doi.org/10.1007/s10729-018-9436-8

Michael, B. V., Siéwé, F., Abdulqudus, A. I., Angarawai, I. I., Ajeigbe, H. A., Ojeiwo, C., & Bako, N. S. (2021). Production efficiency of pearl millet farming households in Nigeria: A translog primal cost system approach. *Journal of Food Security*, *9*(4), 167–182. https://doi.org/10.12691/jfs-9-4-4

Munonye, J. O., Matthew, D. E., Olaolu, M., Onyeneke, R. U., Obi, J. N., Amadi, M., Ibrahim, S. O., Izuogu, C. U., & Njoku, L. C. (2023). The impact of food security and poverty status on rural household farmers in Ikwo, Ebonyi State, Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, *23*(6), 23637–23656. https://doi.org/10.18697/ajfand.123.2345

Munonye, J. O., Osuji, E., Olaolu, M., Okoisu, A., Obi, J., Eze, G., Ibrahim-Olesin, S., Njoku, L., Amadi, M., Izuogu, C., & Azuamairo, G. (2022). Perceived effects of COVID-19 pandemic on food security in Southeast Nigeria. *Frontiers in Sustainable Food Systems*, *6*, 1–18. https://doi.org/10.3389/fsufs.2022.886317

Nain, M. S., Singh, R., Mishra, J. R., & Sharma, J. P. (2015). Utilization and linkage with agricultural information sources: a study of Palwal district of Haryana state. *Journal of Community Mobilization and Sustainable Development, 10*(2), 152-156.

National Agricultural Extension and Research Liaison Services (NAERLS) & Federal Ministry of Agriculture and Rural Development (FMARD). (2020). 2020 wet season agricultural performance survey in Nigeria. Ahmadu Bello University, Zaria.

National Bureau of Statistics (NBS). (2021). Consumption expenditure report. https://nigerianstat.gov.ng/

National Population Commission (NPC) & National Bureau of Statistics (NBS). (2016). Population projections for Nigeria: 2006–2016. National Population Commission.

Nigerian Meteorological Agency (NiMet). (2021). Climate profile of Ebonyi State. https://www.canr.msu.edu/fsg/projects

Niranjan, S., Singh, D. R., Kumar, N. R., Jha, G. K., Venkatesh, P., Nain, M. S., & Krishnakumare, B. (2023). Do information networks enhance adoption of sustainable agricultural practices? Evidence from northern dry zone of Karnataka, India, *Indian Journal of Extension Education, 59*(1), 86-91 http://doi.org/10.48165/IJEE.2023.59118

Njoku, C. L., Mgbeokwere, M. C., Izuogu, C. U., Olaolu, M. O., Azuamairo, G. C., Olesin-Ibrahim, S., & Agou, G. D. (2025). Sex-based constraints in accessing agricultural resources in Ebonyi State, Nigeria. *Journal of Agricultural Extension*, *29*(1), 48–54. https://doi.org/10.4314/jae.v29i1.1

Nwahia, O. C., Balogun, O. S., Balogun, O. L., Emeghara, U. U., Onwegbunam, N. E., & Bala, U. J. (2020). Analysis of technical, allocative and economic efficiency of rice farmers in Ebonyi State, Nigeria. *Russian Journal of Agricultural and Socio-Economic Sciences*, *10*(106), 135–143. https://doi.org/10.18551/rjoas.2020-10.16

Onyeneke, R. U. (2021). Does climate change adaptation lead to increased productivity of rice production? Lessons from Ebonyi State, Nigeria. *Renewable Agriculture and Food Systems*, *36*, 54–68. https://doi.org/10.1017/S1742170519000486

Silva, K. N. N. (2023). Social network to accelerate agricultural technology adoption: Evidence from Hambanthota District, Sri Lanka. *Indian Journal of Extension Education*, *59*(1), 1–6. http://doi.org/10.48165/IJEE.2023.59101 .

Ugwu, J. N., Mbah, G. O., Chidiebere-Mark, N., Tim-Ashama, A., Ohajianya, D. O., & Okwara, M. O. (2017). Technical efficiency of swamp rice farmers in Ebonyi South Agricultural Zone, Ebonyi State, Nigeria. *Current Research in Agricultural Sciences*, *4*(1), 1–6. https://doi.org/10.18488/journal.68/2017.4.1/68.1.1.6