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Comparative Analysis of Technical Efficiency among Smallholder Rice Farmers Using Local and Improved Seeds in North Central Nigeria

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ABSTRACT

The research compared technical efficiency among smallholder rice farmers using local and improved seeds in North Central, Nigeria. A multi-stage random sampling to choose a total sample size of two hundred and thirty-four (234) rice farmers which comprises 88 and 146 smallholder farmers who cultivated local and improved rice seeds, respectively. Primary data were used for the study. The data were collected with the aid of well-structured questionnaire which was subjected to validity and reliability tests. Data were analyzed using descriptive statistics, stochastic production frontier model, and t-test statistics. The results show that the mean age of smallholder farmers utilizing local and improved rice seeds were 43 and 42 years, respectively. The average farm sizes were estimated at 2.00 and 1.99 hectares, respectively. The analysis indicates that farm size, fertilizer, and agrochemicals are significant predictors with a positive impact on rice yields for both local and improved seed users. Furthermore, the inefficiency model reveals that increased farming experience significantly enhances technical efficiency across both groups of smallholder farmers. The mean technical efficiency scores of smallholder farmers who cultivated local and improved rice seeds were 50.2% and 77.2%, respectively. This leaves an inefficiency gap of 49.8% and 22.8%, for improvement, respectively. The study recommends that credit facilities should be made available to rice farmers at low-interest rate devoid of bureaucratic processes. Improved rice seed and other farm inputs such as fertilizer should be made available to smallholder farmers at affordable prices to increase productivity and efficiency.

Keywords:, Agrochemicals, farm, fertilizer, labour stochastic frontier model

INTRODUCTION

Rice (*Oryza sativa*) is one of the most significant staple foods in Nigeria, it makes up roughly 10.5% of the average calorie intake of Nigerians and accounts for 6%

of household expenses (Toluwase et al., 2019). Because of the shift in consumer preference towards rice, rising population, rising income levels, and rising urbanisation, rice consumption is rising quickly in Nigeria (Kamai et al., 2020). Rice (*Oryza sativa*) farming in Nigeria is primarily carried out by smallholder farmers, who cultivate both improved and local rice seed varieties across diverse agro-ecological zones. According to the Food and Agriculture Organization (2019), Nigeria produced approximately 8.9 million metric tons of milled rice, positioning it as one of Africa's largest rice producers. If the right steps are taken, Nigeria may generate 14 million tonnes per year, up from the 8.9 million tonnes. Nigeria is currently the second-largest rice importer after China, with an average of 2.4 million tonnes per year, since rice consumption has overtaken domestic production (Durand-Morat et al., 2019; FAO, 2019). According to Durand-Morat et al. (2019), FAO (2019), and USDA-ERS (2019), rice consumption is expected to expand during the following ten years because of urbanisation and population growth. The demand-supply gap is still evident in the economy despite concerted efforts over the years to increase rice production, including the Agricultural Transformation Agenda, agricultural promotion policies, and the closing of borders against rice importation. Despite the efforts, fewer than 10% of the possible 3.4 million hectares are currently being farmed (Oyinbo et al., 2013; Macauley, 2015). According to Kanu et al. (2014), estimates over 96% of African farmers are smallholders and according to Cadoni and Angelucci (2013), 90 percent of domestic rice production is produced by resource-poor, smallholders' farmers. According to Babura et al. (2017), smallholder farmers play a critical role in Nigeria's rice production, contributing substantially to national food security and rural livelihoods. Improved rice varieties, developed through breeding programs, are designed to possess desirable traits such as high yield potential, drought resistance, quick growth, disease resistance, and improved grain quality (Khan et al., 2015). These varieties are the result of concerted efforts by research institutions and breeding programs to enhance rice productivity and resilience to biotic and abiotic stresses. Conversely, local rice varieties in Nigeria are often traditional landraces cultivated by farmers for generations, adapted to local environmental conditions and cultural preferences (Bello et al., 2020). While local varieties may exhibit resilience to certain environmental stressors and cultural significance, they often have lower yields and increased susceptibility to pests and diseases compared to improved varieties (Ojo et al, 2018). Despite the potential advantages of improved varieties, smallholder farmers continue to cultivate local varieties, influenced by factors such as cost, seed availability, lack of extension services and ignorance of perceived performance (Oluwatoyin, 2021).

Technical efficiency means employing the fewest inputs possible to produce the highest level of output possible given the inputs. According to Farrell (1957), a firm's capacity to produce on the isoquant frontier is correlated with technical efficiency (TE). The farm's production function may prevent a firm of its size from reaching the frontier. However, given their levels of inputs, some firms may produce outputs that are closer to the frontier. The measure of technical efficiency for each firm is the idea of how close the individual production plans are to the maximum levels, as defined by the frontier and given input levels (Ouedraogo, 2015). Takele et al. (2020) measured the technical, allocative, and economic efficiency of rain-fed rice production and identify the factors that affect the efficiency of farmers in Fogera Districts of the Amhara Region. For the study, cross-sectional data were collected from a survey of 230 smallholder rice producers. The study used stochastic frontier production (SFA) and cost function to investigate the variations in the efficiency level of rice producers. The result indicated that the technical efficiency (TE) was higher as compared with the economic efficiency (EE) and allocative efficiency (AE). The average TE ranges between 24% and 93% with a mean of 70%. However, the mean of EE was 24.40 % and the AE 37.30%. Therefore, reduction of cost of production (such as improved input supply systems), warehouse facilities to keep produce and prevent the immediate sale of a product, introducing of a contract marketing system would improve the economic efficiency of the rice farming. Interventions on education and training on female-headed households, reducing family dependency, training of older farmers were vital to increase the EE of rice production. Similarly, improving the farmer’s education level to boost knowledge about new rice technology applications, and frequent training of farmers would enhance the TE of farmers in the study area. Chikezie et al. (2020) analysed the technical efficiency of rice farmers in Ebonyi State, Nigeria. It specifically analysed the levels and determinants of technical efficiency. A multistage sampling technique was adopted for sample selection. A total of 150 well-structured questionnaires were distributed but only 91 were returned. The Cobb-Douglas production function model was used to predict the farm level technical efficiency. Results from the Cobb- Douglas Regression showed a sigma square ($\sigma2$) of 0.06584 which was statistically significant at 1 percent. The technical efficiency scores among the rice farmers ranged from 0.012 to 1.000 with a mean of 0.350. Farm size, quantity of rice seedlings, quantity of fertilizer and quantity of agrochemical all were showed positive correlation with coefficients of 0.93511, 0.08310, 0.11200 and 0.14345 respectively while farm labour showed a negative correlation with technical efficiency. The determinants of technical inefficiency were age, household size and extension visits. This paper advocates the strengthening of existing extension system for timely sourcing of highly improved rice seed varieties and subsidized fertilizer. There is the need to enhance farmers' technical efficiency through adequate training on optimum input mix. The study focused on comparative analysis of technical efficiency among smallholder rice farmers using local and improved seeds in North Central, Nigeria.

MATERIALS AND METHODS

This study was conducted in Niger State and Federal Capital Territory (FCT). Niger state is located between Latitudes 8^0 22' North and $11^0$30' North and Longitudes 30 30' East and 70 20' East. It has a population of 5,556,247 people as estimated by National Bureau of Statistics (NBS), 2016) and is projected to be 7,069,097 in 2023 at a 3.5% growth rate (Population Growth Calculator, 2023). The Federal Capital Territory has a land area of 8,000 square kilometres. It falls within Latitude 9.0765° North and Longitude 7.3986° East. FCT had a population of 3,564,126 people (NBS, 2016) and is projected to be 4,534,563 people in 2023 at a 3.5% growth rate (Population Growth Calculator, 2023).

A multi-stage sampling method was used to select the target respondents. In the first stage, three LGAs from Niger State and three area councils from FCT were randomly selected. In the second stage, two wards each were randomly selected from each of the area councils and LGAs making a total of twelves wards. In the third and final stage, a proportionate simple random sampling was employed to select a total of two hundred and thirty-four (234) rice farmers from a sample frame of five hundred and sixty-five (565) rice farmers in the study area. The sample size (234) comprises eighty-eight (88) and one hundred and forty-six (146) smallholder farmers who cultivated local and improved rice seed was calculated using Yamane (1967) as shown below.

$$\text{n} = \frac{N}{1 + N(e^2)} = \frac{565}{1 + 565(0{,}05^2)} = 234 \qquad (1)$$

Where,

n = Sample Size (Units)
N= Sample Frame (Units)
e = Level of Significance (5%)

Primary data were used for this study. A pilot test was conducted prior to the main test to ensure the reliability and validity of the questionnaire used for data collection. The questionnaire applied in the collection of data for this study was subjected to validity and reliability tests by the supervisors of the study. The reliability test statistics made use of Cronbach's' alpha. It is considered a measure of scale reliability to determine the internal consistency of the questionnaire. The coefficient ranges from 0, implying no reliability, to 1, implying perfect reliability.

$$\propto = \frac{D\bar{H}}{\bar{\gamma} + (D-1)\bar{H}} \qquad (2)$$

Where,
D= Number of Variables,
$\bar{H}$ = Average inter-item Covariance among the Variables, and
$\bar{\gamma}$ = Average Variance.

Validity is the degree to which the test scores from a research study measure what they intend to measure. The survey instrument (structured questionnaire) was face and content-validated by the researcher and supervisors.

The results of the reliability test presented Cronbach's alpha of 0.762 (76%). Cronbach's alpha ranges from zero to one. A reliability coefficient of 0.5–0.7 is considered moderate reliability and hence acceptable (Taherdoost, 2016). The data were analysed using both descriptive and statistics and stochastic frontier production model.

Stochastic frontier production model

The stochastic frontier model following Peter et al. (2020) was used to achieve part of objectives two (ii) and three (iii). The model is expressed thus:

$$W_{ij} = \mathrm{f}(\mathrm{X_i}, \beta) + \varepsilon_\mathrm{i} \qquad (3)$$

Where,
W_{ij}= Output of the Farmer (Local and Improved Rice Seed) (Kg),
X_i= Vector of Actual Quantity Used,
β = Vector of Parameter to be Estimated,
e_i = Composite Error Term; $e_i = v_i - u_i$,
v_i = Decomposed Error Term Measuring Technical Efficiency of the Farmer, and
u_i = The Inefficiency Component of the Error Term.

Stochastic frontier production model is stated explicitly as: -

$$\mathrm{L_n}W_{ij} = \beta_0 + \beta_1\mathrm{L_n}\mathrm{X}_1 + \beta_2\mathrm{L_n}\mathrm{X}_2 + \beta_3\mathrm{L_n}\mathrm{X}_3 + \beta_4\mathrm{L_n}\mathrm{X}_4 + \beta_5\mathrm{L_n}\mathrm{X}_5 + \mathrm{V_i} - \mathrm{U_i} \qquad (4)$$

Where,
W_{ij} = Output of the Farmer (Local and Improved Rice Seed Farmers) (Kg),
X_1 = Farm Size (Ha),
X_2 = Fertilizer Usage (Kg)
X_3 = Agrochemicals (Liters),
X_4 = Labour (Mondays),
X_5 = Seed Usage (Kg),

β_0= Constant Term,
β_1-β_5 = Regression Coefficients,
V_i = Decomposed Error Term Measuring Technical Efficiency of the Farmer, and
U_i = The Inefficiency Component of the Error Term.
The inefficiency component of the stochastic frontier model is stated thus: -

$$U_i = \propto_0 + \propto_1 Z_1 + \propto_2 Z_2 + \propto_3 Z_3 + \propto_4 Z_4 + \propto_5 Z_5 + \propto_6 Z_6 \quad (5)$$

Where: -
$\propto_0$= Constant Term,
$\propto_1$ - $\propto_7$ = Regression Coefficient,
U_i = Inefficiency Component (Local and Improved Rice Seed Farmer),
Z_1 = Farming Experience of Rice Farmers (Years),
Z_2 = Level of Education of Rice Farmers (Years),
Z_3 = Age of Rice Farmers (Years),
Z_4 = Household Size of Rice Farmers (Number),
Z_5 = Number of Contact with Extension Agent (Number of Contact/Month), and
Z_6= Sex of Rice Farmers (1, Male; 0, Otherwise).

The t-Test of Difference between Means

$$\mathrm{t-Stat} = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{{S_1}^2}{n_1} + \frac{{S_2}^2}{n_2}}} \quad (6)$$

Where,
$\overline{X_1}$ = Mean of Improved Seed Users
$\overline{X_2}$ = Mean of Local Seed Users
${S_1}^2$ = Variance of Improved Seed Users
${S_2}^2$= Variance of Local Seed Users
n_1 = Number of observation of Improved Seed Users
n_2 = Number of observation of Local Seed Users

RESULTS AND DISCUSSION

Socio-economic characteristics of smallholder farmers utilizing local and improved rice seeds farmers

Table 1 shows the results of the socio-economic characteristics of Smallholder Farmers Utilizing local and improved rice seeds in the study area. The mean age of Smallholder farmers who cultivated local and improved rice seeds were 43, and 42 years, respectively. This implies that most of the rice farmers were predominantly young, resourceful, and energetic in their economically active age.

This finding is similar to that of Raju et al. (2015), Obot et al. (2022), and Okoro et al. (2023). The mean household sizes were 6 for smallholder farmers who cultivated local and improved rice seeds respectively. This has a direct impact on the supply of labour to the farm because of the potential contributions of these people to the labour available for rice production. The results align with the findings of Antwi and Aborisade (2017), Oloyede et al. (2020), and Mauki et al. (2023). The mean farm size is 2.0 and 1.99 hectares for smallholder farmers who cultivated local and improved rice seeds respectively. This suggests that the farmers were small-scale farmers. The mean experiences were 17, and 14 years for smallholder farmers utilizing local and improved rice seeds respectively. According to Isah and Muhammad (2017), number of years of experience could improve skills and approaches to rice farming practices. The results suggest that the farmers were not new to the rice enterprise, as the majority had over 10 years of experience. The average annual income earned by smallholder farmers utilizing local and improved rice seeds were ₦1,504,886, ₦1, 609,368.8 respectively. This suggests an average monthly income of ₦125,407.17 and ₦134,114.07. The average number of contacts with extension agents within the production seasons were 3 and 4 respectively.

Table 1. Socio-economic characteristics of rice farmers using local and improved seeds

Variable	Unit of Measurement	Local Seeds	Improved Seeds
Age	Years	43	42
Household Size	Number	6	6
Farm Size	Hectares	2	1.99
Faming Experience	Years	17	14
Income from other Farming Activities	Naira	1, 504, 886	1,609,368.8
Contact with Extension Agent	Number	3	2

Source: Computed from Field Data (2024)

Factors influencing technical efficiency of rice production in the study area

Table 2 shows the estimated maximum likelihood results of the stochastic frontier production function for rice farmers in the study area. From the results, farm size ($P<0.01$), fertilizer usage ($P<0.01$), agrochemicals ($P<0.01$), and seeds ($P<0.01$) were significant factors influencing the output of smallholder farmers utilizing local rice seed in the study area. Farm size ($P<0.01$), fertilizer ($P<0.01$), agrochemicals (P<0.01), and labour (P<0.01) were significant factors influencing the output of improved rice seed variety farmers in the study area.

Farm size had positive coefficients and was statistically significant at 1% probability levels in influencing the technical efficiencies of smallholder farmers utilizing local and improved rice seeds. respectively. This means that a 1% increase in the farm size, while holding other variables constant will lead to a 21.4% and 34.7% increase in the output of smallholder farmers utilizing local rice and improved rice seed respectively. This result is in line with Okello et al. (2019), Takele et al. (2020), and Chikezie et al. (2020), who reported that farm size is one of the major factors influencing rice production. Fertilizer usage had positive coefficients and was statistically significant at 1% probability levels in influencing the output of local rice seed varieties farmers and improved rice seed varieties farmers respectively. This implies that a 1% increase in fertilizer input will result in a 30.9% and 20.7% increase in the rice output of local rice seed varieties' farmers and improved rice seed varieties' farmers respectively. This collaborates with the findings of Ouedraogo (2015), Okello et al. (2019), and Takele et al. (2020), who reported that fertilizer input had a positive effect on rice production.

Agrochemicals had positive coefficients and was statistically significant at 1% level of probability in influencing the output of smallholder farmers utilizing local and improved rice seed. This implies that a 1% increase in agrochemicals, keeping all other factors fixed will result in a 23.2% and 20.7% increase in the output of smallholder farmers utilizing local and improved rice seeds, respectively. Seed input had positive coefficients and was statistically significant at 1% level of probability in influencing the output of smallholder farmers utilizing local rice seed. The result shows that a 1% increase in seed input keeping all other factors fixed will lead to a 10.8% increase in the output of smallholder farmers utilizing local rice seed. In the diagnostic statistics, the variance parameters of the production function, which are represented by Chi-squared, lambda, and gamma, were significant at the 1% probability level. This is in line with the findings of Ouedraogo (2015), Okello et al. (2019), Takele et al. (2020), Chikezie et al. (2020), and Mauki et al. (2023).

From Table 2, the inefficiency component revealed that farming experience, contacts with extension agents, and sex were statistically significant variables influencing technical inefficiency of rice farmers. Farming experience had negative coefficients and was statistically significant at 10% probability levels in influencing technical influencing of smallholders utilizing local and improved rice seed respectively. The results suggest that a unit increase in farming experience keeping all other factors constant will lead to a 0.129 unit and 0.067 unit increase in the technical efficiencies of smallholder farmers utilizing local and improved rice seeds. This collaborates with the findings of Ouedraogo (2015), Okello et al. (2019), and Takele et al. (2020).

From Table 2, Contact with extension agents had a positive coefficient and was statistically significant at 5% probability level in influencing inefficiencies of smallholder farmers utilizing improved rice seed. The results suggest that a unit increase in contact with extension agents keeping all other factors fixed will lead to a 0.4022 unit decrease in the technical efficiency of the farmers who cultivated improved rice seed. This finding does not conform with the results of Chikezie et al. (2020) and Mauki et al. (2023). From Table 2, Sex had negative coefficients, was statistically significant at 5% probability levels in influencing technical inefficiency of smallholder farmers utilizing improved rice seed. The results suggest that a unit increase in male farmers keeping all other variables fixed will lead to a 0.776 unit increase in the technical efficiency of the farmers who cultivated improved rice seed.

Technical efficiency scores for smallholder rice farmers utilizing local and improved rice seed in the study area

Table 3 presents the technical efficiency scores of rice farmers in the study area. About 62.50% and 93.15% of the smallholder farmers utilizing local and improved rice seeds respectively, were between 51% to 97% efficient. This means that majority of the farmers are technically efficient. Such efficiency distribution conforms to previous studies carried out on rice farming by Okello et al. (2019), Takele et al. (2020), Chikezie et al. (2020), Peter et al. (2020), and Mauki et al. (2023). The mean technical efficiency of the rice farmers was 50% and 77%, for smallholder farmers who cultivated local and improved rice seeds respectively, leaving a gap of 50% and 23% for improvement.

Therefore, for smallholder farmers who cultivated local rice seed, there is substantial room for improvement, with technical efficiency at 50%. This indicates that they are only utilizing half of their potential productivity. There is a 50% gap that can be addressed through various interventions. For smallholder farmers who cultivated improved rice seed, while their technical efficiency is higher at 77%, there is still a 23% gap for potential improvement. The result also means that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counterpart, then the average farmer could make 20% and 21% cost savings for smallholder farmers who cultivated local improved rice seed varieties farmers respectively.

Table 2. Maximum likelihood estimates of the stochastic frontier production function for rice farmers in the study area

Variables	Local Rice Seed Farmers (N=88)			Improved Rice Seed farmers (N=146)		
	Coefficient	**Standard Error**	**t-ratio**	**Coefficient**	**Standard Error**	**t-ratio**
Technical Efficiency Component						
Farm Size	0.214 ***	0.058	3.67	0.347***	0.062	5.58
Fertilizer	0.309 ***	0.037	8.40	0.207***	0.04	5.22
Agrochemicals	0.232 ***	0.042	5.49	0.207***	0.074	2.80
Labour	0.103	0.065	1.58	-0.143**	0.07	-2.06
Seed	0.108 ***	0.035	3.11	0.019	0.039	0.48
Constant	-1.797 ***	0.463	-3.88	-2.73***	0.515	-5.30
Technical Inefficiency Component						
Constant	-4.151 ***	0.19	-21.84	-4.961***	0.574	-8.64
Farming Experience	-0.129*	0.073	-1.76	-0.067*	0.037	-1.78
Level of Education	0.018	0.388	0.05	0.021	0.123	0.17
Age	0.038	0.096	0.39	0.03	0.025	1.20
Household Size	0.364	0.348	1.05	0.056	0.071	0.79
Contact with Extension Agents	0.304	0.338	0.01	0.4022**	0.2047	1.96
Sex	0.053	1.484	0.04	-0.776**	0.382	-2.03
Constant	-68.279	6772.937	-0.01	-9.632**	4.778	-2.02
Chi-square		1067.808***			913.457***	
Lambda		1.09			4.99	
Gamma		54%			96%	
**** p<.01, ** p<.05, * p<.1*						
Source: Computed from Field Data (2024)						

Test of Hypothesis

The data presented in Table 4 leads to a clear rejection of the null-hypothesis, demonstrating that there is, in fact a statistically significant difference between the technical efficiency of local and improved seed users. The calculated t-value of 14.79 comfortably exceeding the critical t-table value of 1.96, the result indicate that the performance gap is not due to random chance. Farmers utilizing improved seeds achieved a substantially higher mean technical efficiency of 0.772 compared to the 0.502 recorded for local seed users, suggesting that improved variety are a primary driver of productivity. Furthermore, the significantly lower standard deviation for improved seed users (0.017 versus 0.158) implies that the benefits of these seeds are consistent across the larger sample of 146 observations where as local seeds performance is much more volatile and less reliable.

Table 3. Technical Efficiency Scores of Smallholder Farmers Utilizing Local and Improved Rice in the Study Area

Seed	**Local Rice Seed Farmers**		**Improved Rice Seed Farmers**	
	Freq.	**Perc.**	**Freq.**	**Perc.**
0.141-0.50	33	37.50	10	6.85
0.51-0.80	55	62.50	98	67.12
0.81-1.00			38	26.03
Total	**88**	**100**	**146**	**100**
Mean	0.502		0.772	
Min	0.374		0.449	
Max	0.624		0.97	
Standard Deviation	0.069		0.141	
Freq = Frequency	**Perc = Percentage**			
Source: Computed from Field Data (2024)				

Table 4. There is no significant difference between technical efficiency of smallholder rice farmers using local and improved seeds in the study area

Variable	**Technical Efficiency (Values)**
Local Seed Users	0.502
Improved Seed Users	0.772
Standard Deviation (Local)	0.158
Standard Deviation (Improved)	0.017
Number of Observation (Local)	88
Number of Observation (Improved)	146
t-Calculated	14.79
t-Table Critical Value	1.96

Source: Computed from Field Data (2024)

CONCLUSION

The study established that improved seed varieties were significantly more effective in enhancing productivity than local varieties. The farmers utilizing improved seeds achieved the higher mean technical efficiency (0.772) compared to those using local seeds (0.502), a difference validated by a robust t-calculated value of 14.79, which far exceeded the critical threshold. The stochastic frontier model highlighted that while both groups relied heavily on farm size, fertilizer, and agrochemicals, improved seed users benefited more from land expansion (coefficient of 0.347), however they faced challenges with labour management. Furthermore, the inefficiency analysis indicated that farming experience and extension contact played vital roles in reducing waste and improving output. With gamma value for improved seed users, it was evident that 96% all deviations from the maximum potentials output were due to technical inefficiencies rather than random noise. Ultimately, shifting from local to improved seeds, supported by better extension services, remained the most viable pathway for closing the yield gap, and ensuring food security in the region.

RECOMMENDATIONS

To close the 22.8% efficiency gap between local and improved seed users the following recommendations were made:

(i) **Adoption of Improved Seed Varieties**: Smallholder currently using local seeds should shift to using certified improved varieties.

(ii) **Optimization Farm Size and Labour**- Farmers should focus on land size or better land preparation.

(iii) **Enhanced Input Management:** Farmers should adopt precision agriculture techniques, applying the right quantity at the right time.

(iv) **Strengthening Extension Services**. The government should recruit and train more extension officers to provide technical how-to sessions specifically focusing on the management of improved varieties.

(v) **Subsidized Input Distribution Systems**- The government should move beyond general subsidies, and implement a targeted electronic-wallet system in order to ensure access to certified improved seeds and high-quality fertilizer.

(vi) **Gender-Sensitive Agricultural Support**- Policies should specifically target female rice farmers with tailored credit facilities and land tenure security.

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AUTHORS' CONTRIBUTIONS

All Authors contributed equally towards the research and manuscript preparation of the article.

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