



Effects of flooding-induced migration on farm technical efficiency in Rivers State, Nigeria

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ABSTRACT

This study assessed the effects of flooding-induced migration on farm technical efficiency in Rivers State. Data were collected on episodes that occurred between 2011 and 2022 to estimate the trend of flooding in the study area and also farm technical efficiency (TE), specifically from 2022 production activities. Translog Stochastic frontier was estimated and TE generated. The effect of migration on farm's TE was analyzed using endogenous treatment effect model and the average treatment effects were estimated. Results obtained showed that flooding episodes occurred yearly in the twelve years under review. The Stochastic frontier analysis showed that migration has a positive and significant coefficient in the inefficiency model, thus depicting that migration increases technical inefficiency. The TE results showed that migrants operate at 71.17 % efficiency and non-migrants at 74.63 %. This shows that both groups of farmers have room for improvement to achieve efficient production. The result of average treatment effect on the treated (ATT) is significant, with a mean difference of negative 3.85 % and also significant for the untreated (ATU) with 2.01 % value of mean difference. This means that the TE of migrants reduced by 3.85 percent and their expected TE will increase by 2.01 percent if they are not faced with flooding problems and did not migrate. This shows that migration indeed, as seen in the technical inefficiency model, affects TE. It is recommended that government and stakeholders should initiate and execute projects meant to curb flooding in these communities. The ministry of agriculture should engage the Farmers in educational activities on how to manage their farms, combine crops, and proper fertilizer and labour usage for optimum output. These will improve their farm technical efficiency.

1. Introduction

Globally, environmental disasters such as floods are increasingly affecting food production, rural livelihoods, and migration patterns [1, 2]. Floods now account for a significant share of global disaster-related losses, with the United Nations estimating annual economic losses from disasters at \$250–300 billion [3]. These impacts are especially severe in developing regions like West Africa, where high population growth and rapid urbanization heighten exposure to climate risks [4, 5].

In Nigeria, the frequency and severity of flooding events have grown over the past two decades, transforming what were once sporadic occurrences into regular, destructive episodes. The 2012 flood remains one of the most catastrophic, affecting 32 of Nigeria's 36 states including Rivers State and damaging over 1.9 million hectares of farmland. The agricultural sector suffered deeply: rice output fell by 22.4 %, maize by

14.6 %, and cassava by 11.2 % [6, 7]. Coastal states like Rivers are now particularly vulnerable, not only due to their geography but also due to increased tidal surges and rising sea levels [8–11].

Within Rivers State, recurrent flooding has displaced thousands of farming households seasonally, triggering an annual cycle of short-term migration. These households are often relocated into temporary shelters for up to 3–4 months before returning to resume farming activities. Despite multiple studies addressing the causes and impacts of flooding in Rivers State (e.g., risk, mitigation, and disaster preparedness), few have explored the link between flood-induced migration and agricultural productivity [12–15].

Meanwhile, international evidence suggests a complex relationship between migration and farm performance. For instance, Ren et al. [16] found that migration positively influenced technical and fertilizer use efficiency in rice farming in China. Similarly, Nonthakot and Villano

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[17], reported that migration and remittance characteristics enhanced maize productivity in Thailand. However, in Ghana, Adaku [18], found that temporary migration reduced farm production, while permanent migration had no significant effect. These mixed findings suggest that the migration–agriculture link is context-specific.

Studies carried out before now on the recurrent floods in Rivers State [12–15,19,20], focused on the causes, impact, panacea and risk reduction. None looked into how the yearly migratory movement affects farm's technical efficiency. While the impact of flooding on agriculture is known, a substantial research gap exists in comprehending the intricate dynamics of migration and the effect this particular migration due to environmental vulnerability has on farm's technical efficiency in Rivers State.

Therefore, this study seeks to contribute to the empirical literature by examining how seasonal migration due to recurrent flooding affects farm technical efficiency in Rivers State, Nigeria. This is a critical gap, given the increasing frequency of climate-induced displacement and its implications for agricultural development in flood-prone areas.

Flooding in Rivers State and its impact on farmers is explained in details below.

One of the most catastrophic floods to ever hit Nigeria happened between July and October of 2012. Rivers State was among those affected. The government of Nigeria was cautioned by Nigerian Meteorological Agency (NIMET) that above-average rainfall would cause floods in 12 important states, but the government disregarded the caution. Together with the water released from the Lagdo dam in Cameroon, this caused the Niger and Benue rivers to overrun their banks, causing enormous floods [21]. The effects of the flood were terrible. Fatalities were documented, individuals were rendered homeless, agricultural lands were compromised, there was contamination of water, and economic operations were entirely suspended. The cost of transporting individuals increased because there were limited transportation options available to the affected communities, which were solely local canoes and speedboats. In numerous locations nationwide, there was the incursion of reptiles, including snakes and crocodiles, due to the flood. Agricultural producers nationwide incurred substantial financial deficits. Challenges were posed by food production, food marketing, and food storage. Prices of goods increased, and there was also a sudden closure of schools. The floods decreased food production along flood plains and damaged about 1.9 million hectares of agriculture. These areas saw a reduction in rice output of 22.4 %, a reduction in maize production of 14.6 %, and reductions in the production of cowpea (6.3 %), soyabean (11.2 %) and cassava [21]. The 2012 floods claimed the lives of 136 cattle, 3 million chickens, and 12 million goats. According to estimates from the National Emergency Management Agency (NEMA), the floods incurred an aggregate expenditure of 2.29 trillion-naira, equivalent to 2.83 % of the adjusted Gross Domestic Product of 81 million naira for 2013. The nation's food security was put in jeopardy as hundreds of farmers were forced out of their places of residence and agricultural products were destroyed, making the floods dubbed the worst in recent memory. Major staples in the localities, such as yam, maize, plantain, cassava and pawpaw, were among the crops most adversely affected by the flood [22]. Out of the 36 states in Nigeria, 32 were hit by this devastation; Rivers State was one of the worst-hit states [21]. The relief materials to the affected people were not enough, yet the affected states' governors ordered that the flood victims evict their homes and put-up temporary shelters for them. Due to the fear of thieves breaking into their homes, several flood victims refused to leave their towns. Prior to this time, there had been a flooding episode in 2013 but it was not as devastating as the 2012 episode. There is indeed an understatement of 50 % in the estimation of the losses from the 2012 episode.

About 2.5 trillion US dollars are lost in the world economy due to this devastation in West Africa that includes Nigeria. [21]. West Africa's population growth and urbanisation patterns since the turn of the century suggest that an increasing number of people may be impacted by

flooding episodes in the coming years. According to the United Nations Office for Disaster Risk Reduction (UNISDR), the 2015 Global Assessment Report on Disaster Risk Reduction (GAR 15), indicates an average of between \$250 billion and \$300 billion of yearly economic losses resulting from catastrophes [23]. The Nigeria Hydrological Services Agency's director general in 2015 issued a warning in the capital city of Abuja at the annual flood outlook presentation. The nation's danger areas were split into three categories: lowland flood areas, medium risk, and high risk. The river basins of Niger-Benue, Sokoto-Rima, and Anambra had predictions for high flooding; Biase, Munya, Chikum, Shinkafi, and Etiosa, among others, had predictions for localised flooding; while Rivers, Lagos, Bayelsa and Delta states had predictions for coastal due to rising sea levels and tidal surge. As a result of this recent warning, it is necessary to examine the methods farmers currently employ to prepare for flooding, the steps taken by organisations and government agencies to lessen flooding, and the steps the government has taken to manage flood disasters.

2. Methodology

The study area, research design (data source, type and data collection tools, sample size, sampling procedure), and analytical tools used in the study are enumerated in this section.

2.1. Study area

One of Nigeria's 36 states, Rivers State is centred in the country's South-South geopolitical zone with its capital, Port Harcourt. It is bordered to the east by the states of Abia and Akwa Ibom, to the west by the states of Bayelsa and Delta, to the north by the states of Anambra and Imo, and to the south by the Atlantic Ocean. The population was 5,198,716 in the 2006 census, and was projected as 7,492,366 in 2023. Its coordinates are Latitude 4.75°N and longitude 6.50°E, and it encompasses an area of 11,077 km² (4,277 m²). The Ijaw, Ikwerre, Etche, Ogoni, and Ogba/Egbema are the predominant ethnic groupings. The primary means of subsistence for the populace is agriculture, and food production serves as the cornerstone of state agriculture policy.

Nigeria's seventh most populous state is Rivers State. The linguistic diversity of the state is especially well-known; it is estimated that 28 indigenous languages, including Ikwerre, Ogba, the Etche, Abua, Ogoni, Igbo, and Ijaw languages among others, are spoken in Rivers State. Rivers State is the 26th largest state in Nigeria by geographical area, and is traversed by numerous rivers, including the Bonny River. These rivers shape the topography of the state.

2.2. Research design

2.2.1. Data source, type and data collection tools

Primary and secondary data were used for the study. Primary data were collected from rural farmers in one of the three Agricultural Zones in Rivers State where the flooding episodes are prevalent and farmers engage in crop production. The households included in the sample were interviewed using a structured questionnaire coded into KoboCollect software. The questionnaire gathered a variety of data regarding households' socioeconomic circumstances, their production activities and also the coping strategies adopted in mitigating the impact of flood in their farms. Information was also collected from households in communities that do not experience flooding and migration to serve as our control group. Crop farmers were included in the study while those who rear livestock alone were excluded. Household heads who are eighteen years and above were also included, whether male or female. Secondary data were collected from National Emergency Management Agency (NEMA) on the flooding episodes in the study area over the period 2011–2022.

2.2.2. Sample size determination

This study included a sample size of 440 farmers. Using the mathematical method developed by Miller and Brewer [24] the study's sample size was determined from the sample frame. The following is the formula;

$$n = \frac{N}{1 + N(\alpha)^2} \quad (1)$$

Where;

N = Sample frame

n = Sample Size

α = Confidence Interval.

A 95 % confidence interval and 5 % margin of error were used in this study. The reason behind this was that in contrast to other physical sciences, the study included human subjects, whose accuracy of information is prone to biases. So, α used is 0.05. Also, 70 % of the population of the area under study form the farming population, so the sample frame is 1258670.

Consequently,

$$n = 399.87 \text{ (approx. 400)}$$

Considering the specified confidence level and margin of error, the sample size of 400 farmers was calculated by applying the formula above. Consequently, 400 with an additional 10 percent farmers was included in the study's sample (440). This information is shown in Table 1.

2.2.3. Sampling procedure

A sample of 440 households from one out of the three agricultural zones of Rivers state—Ahoada, Degema, and Eleme—were used for this study. Every agricultural zone has vast, rich farmlands and produces a multitude of products, including vegetables, plantains, rice, cassava, yam, and cocoyam. Nevertheless, some regions are more naturally fertile than others, which means they produce more food, while other regions are more conducive to fishing. There is a total of 23 Local Government Areas (LGAs): 7 in the Ahoada Agricultural Zone, 8 in the Degema Agricultural Zone, and 8 in the Eleme Agricultural Zone. Degema is primarily for fish farmers while Eleme does not experience flooding episodes, therefore both zones were excluded for the research and only Ahoada zone included.

Multi-stage random sampling technique was used to guarantee accurate representation.

Using simple random sample technique, the first stage involved clustering the farming households into migrants and non-migrants. Three LGAs were chosen for each cluster from the 7 LGAs in this Agricultural Zone that produce primarily crops (3 LGAs experience flooding and 4 do not). There were six LGAs chosen in all, three LGAs for the treatment group in cluster one (migrants) and three for the control group in cluster two (non-migrants).

Table 1
Sampling procedure.

Captured LGAs (Migrant group)	Farming Population (70 %)	Sample size	Captured LGAs (Non-migrant group) ^a	Farming Population (70 %)	Sample Size
Ahoada East	167,440	58	Emohua	202,440	71
Ahoada West	250,880	88	Omuma	101,080	35
Ogba-Egbema-Ndoni	285,180	100	Etche	251,650	88
Total	703,500	246		555,170	194

^a Control group.

Source: Author's computation.

Using simple random sample technique, two communities were selected at random from each of the Local Government Areas in stage two. Sampling of 12 communities were done in all, six from areas affected by flooding that experiences migration and six from areas without flooding and forced migration issues.

The third stage involves employing a systematic random sample technique to select 440 households in total, from the 12 communities. Sample size of 246 was selected for the treatment group and 194 for the control group based on their population sizes. The information on how this was done is also presented in Table 1.

The sampling frame for this study comprised exclusively of crop farmers residing in flood-prone agricultural communities across selected Local Government Areas (LGAs) of Rivers State, Nigeria. Animal farmers were excluded, as the research focused solely on crop production systems and their relationship with flood-induced migration and farm technical efficiency. A multistage sampling technique was adopted. First, three LGAs with high exposure to seasonal flooding, Ahoada East, Ahoada West, and Ogba/Egbema/Ndoni were purposively selected. Within each LGA, communities were randomly selected, followed by random sampling of farming households. The sample size of 440 crop-farming households was proportionally distributed across the selected LGAs to ensure representation of the flood-affected agricultural population. The assumption of homogeneity within the crop farming population was considered valid due to similarities in environmental exposure, cropping systems, and socioeconomic conditions across the study area. Furthermore, the adequacy of the sample size allows for the application of inferential statistical techniques, supported by the Central Limit Theorem (CLT), which states that the sampling distribution of the mean will approximate normality as the sample size increases, regardless of the population's underlying distribution [25].

2.3. Analytical tools

The first objective of this study was to describe the trend in flooding episodes, migration and return migration of farming households in the study area. To achieve this, descriptive statistical tools such as tables, graphs, mean differences and percentages were used.

The second objective was to examine the effect of flooding-induced migration and return on farm productivity (technical efficiency). This study adopted and amended the approach of Ren et al. [16], to examine the effect of flooding-induced migration on farm technical efficiency. To estimate these effects, Endogenous Switching Regression (ESR) model was used. Additionally, Propensity Score Matching (PSM) was incorporated to complement the ESR approach so as to provide more robust estimates of the effects of migration on technical efficiency.

To examine the effect of flooding-induced migration and return on farm productivity (technical efficiency) in Rivers State, the Cobb Douglas and Translog Stochastic Frontiers were used to run two production functions and the one that gave the best fit was chosen. Endogenous switching regression analyses was then done to estimate the effect of migration on farm's technical efficiency. PSM analysis was also carried out for robustness check. Technical efficiency reflects the economic performance of farms, quantifiable by their capacity to reduce input usage relative to output levels. To measure technical efficiency, the production function was firstly defined. The Translog production function is stated as follows;

$$\ln Y_i = \beta_0 + \sum_{j=1}^n \beta_j \ln X_{ij} + \frac{1}{2} \sum_{j=1}^n \sum_{s=1}^n \beta_{js} \ln X_{ij} \ln X_{is} + \sum_{k=1}^n \alpha_k D_{k+} V_i - U_i \quad (2)$$

Where;

Y represents the farm output (in kilograms/ha) (Yield);

X1 represents the total quantity of seeds (in kilogrammes);

X2 denotes the total area cultivated (in hectares);

X3 represents the fertiliser (composed of nitrogen, phosphorus, and

potassium), (measured in kilogrammes)

X4 denotes the quantity of insecticide administered (in litres);

X5 represents the cumulative labour utilised before and throughout the harvesting process (man-days);

Employing a dummy variable to account for the occurrence of zero observations allows for the unbiased estimation of the parameters in Cobb-Douglas production functions [26].

D1 is the dummy variable for fertiliser, assigned a value of 1 when $X3 = 0$ and 0 when $X3 > 0$;

D2 serves as the dummy variable for pesticide, assigned a value of 1 when X4 equals 0 and 0 when X4 exceeds 0;

D3 is the dummy variable representing soil fertility, assigned a value of 1 if fertile and 0 if otherwise.

D4 is the dummy variable for extension contact with a value of 1 if the respondent had access to an extension agent and 0 otherwise;

D5 serves as the dummy variable for migration, assigned a value of 1 when the household undergoes migration and 0 when it does not.

The subscripts j, i, and k denote the j-th input ($j = 1, 2, \dots, 5$), i-th farmer ($i = 1, 2, \dots, 440$), and k-th control variable ($k = 1, \dots, 5$), respectively.

The α s and β s are parameters to be evaluated;

V_i represents the noise component;

U_i is the non-negative technical inefficiency component.

The technical efficiency (TE) of the i-th farm is defined as follows:

$$TE_i = \exp(-u_i) \quad (3)$$

The technical efficiency index (TE_i) equals 1 when the farm operates at optimal efficiency and equals zero when it is completely inefficient.

The next step in the empirical analysis involves assessing the effect of migration on technical efficiency. The variable of interest is technical efficiency, which assesses the economic performance of farms. The treatment variable is migration (M_i). The treatment variable, migration (M_i), is defined as one if the household migrated during the most recent flood disaster and zero otherwise. Nevertheless, households' migration decisions are influenced by multiple circumstances; so, the choice to migrate is not arbitrary. Consequently, to assess the causal impact of migration on agricultural production, the Endogenous Switching Regression (ESR) method is employed to address the self-selection bias associated with migration. The selection equation in the first stage of the switching regression is specified as:

$$G_i^* = \alpha X_i + \varepsilon_i$$

where

$$G_i = \begin{cases} 1, & \text{if } G_i^* > 0, \text{ and} \\ 0, & \text{if otherwise} \end{cases} \quad (4)$$

Where;

G_i^* = vector of the binary unobservable or latent variable for the utility of migration to the farmer.

G_i = vector of the binary dummy (1 = migrate, 0 = Otherwise) for the migration equation where the farmer either migrated or did not.

X_i = vector of exogenous variables including the farm and household characteristics.

α = vector of parameters to be estimated.

ε_i = the error terms.

The two regimes for the technical efficiency outcomes are specified as:

$$TE_{1i} = \beta_1 Z_{1i} + \mu_{1i}, \text{ if } G = 1 \text{ and} \quad (5)$$

$$TE_{0i} = \beta_0 Z_{0i} + \mu_{0i}, \text{ if } G = 0 \quad (6)$$

Where;

TE_{1i} and TE_{0i} = the technical efficiency outcomes for migrants and non-migrants respectively.

Z_i = represents a vector of exogenous variables considered to influence TE_{1i} and TE_{0i} . At least one variable in X_i is excluded from Z_i .

The endogeneity test was conducted using the two-stage residual inclusion (2SRI) method. This approach, also known as the control function approach, accounts for unobserved factors that may simultaneously influence both the treatment (migration) and the outcome (technical efficiency). The procedure involved first estimating a logit model of migration using theoretically valid instruments, and then including the first-stage residual as an additional regressor in the second-stage technical efficiency equation. A statistically significant coefficient on the residual term would indicate that migration is endogenous and correlated with unobserved determinants of technical efficiency. In such a case, treating migration as exogenous would result in biased estimates. Therefore, the subsequent analysis addresses this endogeneity by applying an endogenous treatment effect model.

2.3.1. The endogenous treatment effects

To model the effects of migration on technical efficiency, we estimate the endogenous treatment effect model. In Stata, this is modelled simultaneously in two stages and also accounts for selection bias. First, it is assumed that a farmer chooses any one of the migration statuses that maximize their utility. The first stage estimates a logit model with the outcome equation using sub-samples, while the second stage estimates the selection equation (eqn. (4)) using the full sample.

The outcome equation for the individual migration statuses is specified as;

$$E(TE_i = 1 | d_{ik}, z_i, \bar{z}_i, \varepsilon_i) = z_i \beta + \sum_{k=1}^k Y_k d_{ik} + \sum_{k=1}^k \lambda_k \xi_{ik} + \varepsilon_i \quad (7)$$

Where;

TE_i = technical efficiency.

z_i = is a set of exogenous covariates with associated parameter vector β .

d_{ik} = binary variables for observed treatment choice.

Y_k = is the treatment effects relative to non-migrants.

ξ_{ik} = is a set of latent factors.

$E(TE_i = 1 | d_{ik}, z_i, \bar{z}_i, \varepsilon_i)$ = is a function of each of the latent factors ξ_{ik} .

The resultant model was analyzed with Stata tool using a Maximum Likelihood technique.

2.3.2. Propensity score matching

The final phase in the empirical analysis involves employing the propensity score matching method as a robustness check for the Maximum likelihood estimates of treatment effects for the ATT. This was used because it's mostly used in migration related studies. Ren et al. [16] and Sauer et al. [27] all used PSM in their studies on migration and effects on farm's technical efficiency. PSM establishes an artificial control group to assess a program's counterfactual [28]. PSM enables the formation of a comparable treatment and control group based on observable exogenous factors influencing migration, facilitating the assessment of causal effects through the comparison of outcome variable disparities between the constructed treated and non-treated groups. Households in the treatment group (migrant households, $M_i = 1$) or the control group (non-migrant households, $M_i = 0$) have potential outcomes Z_{0i} if untreated and Z_{1i} if treated. The effect of migration on the outcome variable for migrant and non-migrant groups can be expressed as follows;

$$E(Z_{1i} | M_i = 1) - E(Z_{0i} | M_i = 1), \text{ for the migrant group} \quad (8)$$

$$E(Z_{1i} | M_i = 0) - E(Z_{0i} | M_i = 0), \text{ for the non - migrant group} \quad (9)$$

In empirical estimation, we employ the most often utilised Nearest Neighbour (NN) matching for PSM. Specifically, we apply NN with two matching partners and restrict the matching within the common support.

3. Results

The results of the estimation of the trend in flooding episodes and the effects of flooding on farm technical efficiency are presented in this section.

3.1. Descriptive statistics

3.1.1. Farmer characteristics

The results for the socio-economic characteristics of farmers in the study area are presented in Table 2.

Findings reveal that majority of the farmers are assigned lands in the community once married and thereafter go into farming. 96 % of the migrants are married while 96 % also of the non-migrants are married. Monogamy is prevalent in the study area with migrants having a 71 % figure and non-migrants, 78 %. The mean age with married partner for migrants is approximately 32 years, while that of non-migrants is approximately 31 years. The mean age of migrant farmers is approximately 63 years while that of non-migrant farmers is 60 years. The males dominate in all the two groups of farmers under study. Result shows that

98 % are males in migrant group while 93 % are males in non-migrant groups respectively. For females, 2 % exist in migrant group while non-migrants have 7 %.

The average years of farming experience for the migrant group is approximately 29, that of non-migrants is 28 years. The mean household size for the migrant farmers is approximately 8 people per household while the mean household size for non-migrants is approximately 7 persons per household. Migrant farmers were also found to be educated to several levels, with only 6 % having no formal education. For the non-migrants, only 2 % lack formal education while the rest are educated to several levels.

The test of mean difference shows a significant difference exists between the migrants and non-migrants' type of marriage, household size, gender, age, age with married partner, ethnic group and level of education.

3.1.2. Farm-specific factors (socio-economics)

The results on crop combinations grown by farmers in the study area, are shown in Fig. 1.

The results show that about 56 percent of the farmers who plant cassava only, are migrants while the remaining 44 percent are non-migrants. Fifty percent of those who grow maize only, are migrants and the other 50 percent are non-migrants. All the yam and plantain producers fall under the migrant communities as the result showed yam and plantain are not key crops grown among the non-migrants.

Table 2

Socio-economic statistics of farmers in the study area.

Variable	Migrants (Treatment)		Non-migrants (Control)		Diff. in mean	P-value
	Mean	Std. dev.	Mean	Std. dev.		
Family type					−0.003	0.914
Nuclear	0.915	0.280	0.918	0.276		
Extended	0.085	0.280	0.082	0.276		
Marriage type					0.072*	0.086
Polygamous	0.290	0.454	0.220	0.413		
Monogamous	0.711	0.454	0.784	0.413		
HHSize	7.711	2.929	6.840	2.676	−0.871***	0.001
Gender					0.043**	0.029
Male	0.976	0.155	0.933	0.251		
Female	0.024	0.155	0.067	0.251		
Age	62.882	9.720	60.041	11.210	−2.841***	0.005
Marital status					−0.032	0.638
Married	0.963	0.188	0.959	0.199		
Separated	–	–	0.021	0.142		
Divorced	–	–	0.005	0.072		
Widowed	0.033	0.178	0.015	0.124		
Never married	0.004	0.064	–	–		
Age with married partner	31.821	4.180	30.912	4.186	−0.909**	0.024
Years of farming experience	28.780	9.520	28.170	9.646	−0.616	0.504
Religion					−0.135	0.245
No religion	0.024	0.155	0.046	0.211		
Catholic	0.374	0.485	0.418	0.494		
Protestant	0.297	0.458	0.258	0.439		
Ch'matic	0.215	0.412	0.201	0.402		
Islam	0.008	0.090	0.005	0.072		
Traditionalist	0.081	0.274	0.072	0.259		
Ethnic groups					−71.740***	0.000
Ekpeye people	0.236	0.425	0.005	0.072		
Ikwerre	–	–	0.361	0.481		
Igbo	0.004	0.064	0.619	0.487		
Ijaw	–	–	0.005	0.072		
Ogba	–	–	0.005	0.072		
Other	0.760	0.428	0.005	0.072		
Education					0.527***	0.000
None	0.057	0.232	0.015	0.124		
Primary	0.549	0.499	0.454	0.499		
Secondary	0.309	0.463	0.273	0.447		
Polytechnic	0.024	0.155	0.026	0.159		
University	0.061	0.240	0.227	0.420		
Uni. (postgraduate)	–	–	0.005	0.072		

Source: Field survey, 2024

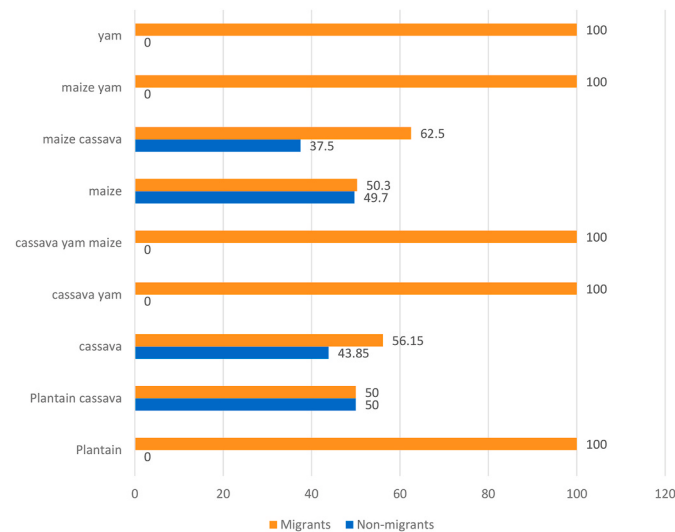


Fig. 1. Distribution of Respondents who cultivate various crops by household type (%).

Source: Field Survey, 2024.

The various crop outputs, land sizes where these crops are grown and farm input use information are shown in Table 3.

Findings reveal that the mean cassava output of migrants is more than that of non-migrants (2795.13 kg and 2772.07 kg respectively). Migrants also harvest more plantain (1350 kg as against 200 kg). There is no recorded yam production by the respondents in the non-migrant communities who were a part of this research. Only the migrants recorded yam production. The mean output from maize is 4217.15 kg for the non-migrants while that of migrants is 1482.03 kg. This shows that the non-migrants have more maize output than their migrant counterparts who encounter flood. The losses experienced by the migrants due to flooding explains the reason for this difference. Losses come from flooded farms during harvest or from immature harvested outputs in early harvest.

The mean of seeds in kg planted by the migrants (226.61) is more than the mean for non-migrants (222.55). Result also shows no mean difference in the amount of fertilizer used by both categories of farmers. This result of fertilizer use (14.17 kg) shows minimal usage for all the respondents. This is because the lands are left to fallow over time and allowed to regain its soil fertility. Responses to the question on how fertile the land is shows that some farmers have their lands fertile and others as very fertile. All the farmers also practice fallowing. Therefore, the farmers apply fertilizers minimally.

Table 3

Summary statistics of farm-specific factors.

Variable	Migrants		Non-migrants		Diff. in mean	P-value
	Mean	Std. dev	Mean	Std. dev		
Output (kg)						
Cassava production	2795.134	1608.712	2772.072	1358.620	−23.062	0.903
Maize production	1482.031	927.133	4217.151	2350.307	2735.12***	0.000
Yam production	763.889	577.471	0	0	−	−
Plantain production	1350.000	919.239	200.000	−	966.667	−
Land size (ha)						
Land size for cassava	6.500	3.709	6.279	3.227	−0.221	0.617
Land size for maize	6.255	4.039	5.488	2.969	−0.767	0.150
Land size for yam	3.778	2.803	0	0	−	−
Land size for plantain	3.500	2.121	1.000	−	2.667	−
Other composite inputs						
Seed (kg)	226.610	319.851	222.546	335.350	−4.063	0.897
Fertilizer (kg)	14.167	0.913	14.167	0	3.88x10 ^{−8}	1.000
Total labour (Man-days)	206.528	244.565	265.062	399.102	58.533*	0.059

Source: Field survey, 2024

Result also shows that the non-migrants use more labour in man-days than the migrants who encounter flooding (265.06 and 206.53 respectively). This difference could be explained by the number of months spent outside the community away from the farm and farming activities during the flooding episodes. The farmers migrate out of their communities for three-four months every year and return when the waters recede. The non-migrants do not experience these flooding episodes and so remain in their communities engaging in farming activities which utilize labour.

3.2. Trends in flooding episodes, migration and return migration of farming households

The mean values of household members that migrated during flooding episodes, number that returned, number of months they stopped farm operations, and the mean value of flooding episodes between 2011 and 2022 is represented in Fig. 2.

The bar chart shows the mean values for various flooding-related metrics across the local government areas (LGAs). Each bar represents the mean value of a specific metric, with corresponding values labelled on the bars. It can be seen that farm operations stopped for three months each year between 2011 and 2022. The flooding episodes also can be seen to have occurred twelve times in the twelve years under review, in the study area. On the average, eight persons migrated from each household and seven persons returned home after the flooding episodes. This number that migrated represents the average household size for the migrants, thus all household members for the affected communities

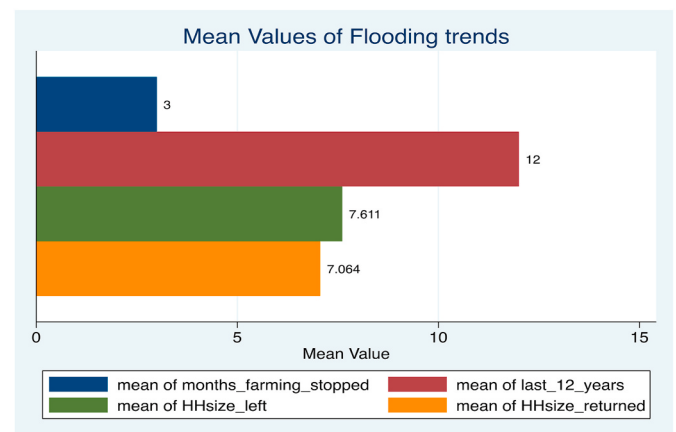


Fig. 2. Mean values of flooding trends.

Source: Field survey, 2024

migrate each episode.

The results also show that all the respondents migrated during the flooding episodes in the twelve years under review, to several shelters. For the 2022 season, Fig. 3 gives a description of the percentage migrations to Internally displaced persons' camps (IDP), family members houses and urban areas.

Out of 246 migrants, 79 % (195) migrated to IDPs, 20 % (48) migrated to family members houses in other communities and 1 % (3) migrated to urban areas during the 2022 flooding episode. This goes to show that majority of the migrants end up in IDPs during the flooding episodes. Data was also collected and analyzed on the number of migrants that left during this time and those that returned home after the floods.

This information was tabulated for the various migrants across the three LGAs affected and is represented in Table 4.

On the average, the trend is the same for all the LGA as regards stoppage of farming operations and number of flooding episodes. There is at least one person on an average per household, from each of the affected local government areas who did not return. This goes to show that migration cuts across all the affected areas and no farmer is left out. This is the trend of episodes which has lasted for decades, with no solution. These findings are in line with the work of Ajibade et al. [29], who analyzed data from 240 smallholder rice farmers in Kwara state Nigeria, an area faced with recurring flooding episodes. With each flooding episodes, these farmers also move into IDPs, family members houses and urban areas.

Data collected showed that households who identified as migrating to other family members houses and urban areas are mostly those who do not return. All the respondents stated that while in the shelter camps, there is no opportunity for new skill acquisition and there is also no opportunity to non-farm activities so as to earn income. The federal government of Nigeria feeds them while in the camps and that is all they get as relief. As regards how often this happens, this trend has persisted as long as they have known and been members of these communities. The river bordering on these four LGAs (Orashi River) is the reason this happens and has continued to happen.

Also, like the work of Ajibade et al. [29], who analyzed data from smallholder rice farmers in Kwara state Nigeria, the experience is the same. They too are bordered by a river which overflows its banks at certain times of the year and the episode occurs yearly.

The trend of flooding across the affected LGAs covered in this study is yearly, with a minimum of three months in a year and cuts across all the areas. All farmers migrate at these times, stop farming and are away until the water recedes. When the flood goes away, most members of households return while others change location to other unaffected communities and some to the city. There is indeed the need to curb the flood or reduce it to the barest minimum.

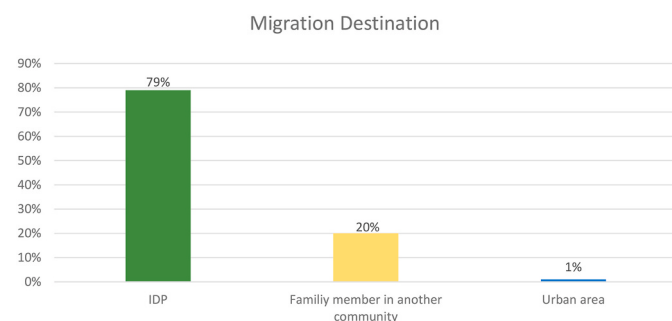


Fig. 3. Migration destination of migrants.

Source: Field survey, 2024

Table 4

Summary of flooding trends by local government areas.

	Ahoada East		Ogba Egbema-Ndoni		Ahoada West	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
No. of Months Farming Stopped	3.00	0.00	3.00	0.00	3.00	0.00
No. of Episodes (2011–2022)	12.00	0.00	12.00	0.00	12.00	0.00
No. Migrated	7.00	3.50	8.00	2.35	8.00	3.22
No. Returned	6.00	2.87	7.00	2.70	7.00	3.29

Source: Field Survey, 2024.

3.3. Effects of flooding-induced migration and return on farm technical efficiency

Data were collected on farmer's crop production activities for the 2022 planting season and analyzed. Cobb-Douglas and Translog stochastic frontiers were fitted and analyzed using the crop production activities. Based on a Wald test of the additional squared and interaction terms, the null hypothesis of joint insignificance was rejected ($X^2(3) = 17.52$, $p = 0.0006$), indicating that the Translog model provides a statistically better fit than the Cobb Douglas specification. The Translog model was therefore chosen. The results of the production function, technical inefficiency and error terms are presented in Table 5. Finally, the mean technical efficiencies were calculated for the migrant and non-migrant groups respectively. These results are also presented in Table 5.

The results of the stochastic frontier analysis provide insights into the efficiency of agricultural production in the study area. The model is statistically significant with a Wald chi-square value of 23.24 and a probability value of 0.0003, indicating that the factors included in the model significantly affect agricultural output. The log likelihood value of -530.64 further supports model convergence and fit. The gamma parameter (γ) which is 0.9131 also confirms that a large proportion of the total error is attributable to inefficiency rather than random noise,

Table 5

Results of stochastic frontier analysis.

	Coefficient	Std. Error	P-values
<i>Translog Production Function</i>			
LnSeed	0.0871*	0.0510	0.088
LnLabour	0.2094*	0.1227	0.088
LnSeed squared	-0.0455**	0.0180	0.012
LnLabour squared	-0.1456	0.1033	0.159
LnSeed x LnLabour	-0.0452	0.0288	0.116
Constant	0.6487	0.0920	0.000
<i>Technical Inefficiency</i>			
Migrants (RC = Non-migrants)	0.6679***	0.0541	0.000
Type of Family	0.0009	0.0728	0.990
Monogamous (RC = Polygamous)	0.1809***	0.0506	0.000
Household Size	0.0389***	0.0080	0.000
Female (RC = Male)	-0.0010	0.1114	0.993
Age	-0.0018	0.0017	0.288
Primary (RC = No Education)	0.0397	0.0898	0.658
Secondary	-0.0226	0.0901	0.802
Polytechnic	0.4099***	0.1428	0.004
University	0.3820***	0.0985	0.000
Uni.(postgrad.)	1.8762***	0.3852	0.000
σ^2	0.2655	0.0191	
γ	0.9131	0.0228	
σ_{u2}	0.2424	0.0197	
σ_{v2}	0.0231	0.0059	

No. of Observation: 440; Wald Chi2(5): 23.24; P-value: 0.0003; Log Likelihood: -530.64 .

Mean technical efficiency (TE) for migrants = 0.7117, non-migrants = 0.7463.

Note: ***, **, * represent 1 %, 5 % and 10 % significance levels, respectively. RC, reference category. TE: 0 score = inefficient, score 1 = efficient.

Source: Field survey, 2024.

which validates the appropriateness of the model specification.

In the production function section, the coefficient for seed (LnSeed) is 0.0871 with a p-value of 0.088 suggesting a significant positive impact on output. This implies that increasing seed usage increases the output level. The coefficient of Labour (LnLabour) is significant with a value of 0.2094. This implies that a unit input of seed will result in a 0.2094 percent increase in output level. The coefficient for the square of seed (LnSeed squared) is -0.0455 which is significant. This result means that as additional units of seed is added, the output level increases at a decreasing rate. That is, the input seed has diminishing marginal returns on the output. The coefficient for the square of labour (LnLabour squared) is -0.1456 which is not significant. The interaction coefficient of seed and labour (LnSeed x LnLabour) is -0.0452 which is not significant.

Fertilizer input was excluded from the regression because result showed minimal fertilizer use in the study area. The mean fertilizer use recorded is 14.17 kg per hectare which is very minimal and therefore, was excluded in the regression.

The next section technical inefficiency, shows the impact of various factors on the technical inefficiency of production. The variable migrants have a positive and significant coefficient of 0.6679. This shows that migration increases technical inefficiency when compared to their non-migrant counterparts. Indeed, the movement yearly due to flooding episode is associated with increased inefficiency. This result is in line with the findings of several researchers who carried out studies on the effect of migration on farm's technical efficiency. Migration was found to have led to lower technical and fertilizer use efficiency among rice farmers in China [16,30].

The variables monogamous marriage with reference category polygamous has positive influence on technical inefficiency. Household size also is statistically significant at 1 percent level and influences inefficiency positively. Age has a negative and insignificant influence on technical inefficiency. The variables polytechnic, University and post-graduate are all positive and significant. This means they contribute to technical inefficiency but the result from the socioeconomics of the farmers shows only few respondents in these categories of education.

In the last section, the sigma_u2 (variance of inefficiency) is 0.2424 and sigma_v2 (variance of the error term) is 0.0231. The technical efficiencies of farms were then calculated for the individual farmers. The "if" condition was used to separate this result for migrants and non-migrants and result shows that migrants operate at a mean of 71.17 percent efficiency and non-migrants at 74.63 percent. This goes to show that both groups of farmers have room for improvement on their TE score. The migrants have 28.83 percent improvement to make while the migrants have 25.37 percent improvement to makes so as to achieve 100 percent technical efficiency in their farms. Of a truth migration happens yearly but, operating at an efficient level given inputs is not a function of output levels. Other factors like managerial skills, farming experience, proper information on input-output combinations that can enhance efficient production etc. all contribute to higher technical efficiency. These are lacking for both migrants and non-migrants alike. The exact difference in the technical efficiency of these two groups was estimated using endogenous treatment effect.

3.3.1. Technical efficiency distribution

The distribution of technical efficiency scores was analyzed and the results are shown in Table 6.

The distribution of technical efficiency scores differed significantly between migrants and non-migrant households. The 10th, 25th, 50th, 75th and 90th technical efficiency scores for non-migrant households were consistently higher than those for migrant households, suggesting a leftward shift in the efficiency distribution among migrants. The difference was statistically significant (Wilcoxon p-value of 0.0119 < 0.05). This indicates that migration status is associated with lower farm technical efficiency.

Density distribution of the technical efficiency scores was also

Table 6

Distribution of technical efficiency scores by migration status.

Percentile	Migrants	Non-migrants
10th	0.4950	0.6912
25th	0.7009	0.7043
50th	0.7412	0.7503
75th	0.7858	0.7959
90th	0.7973	0.8030
Mean	0.7117	0.7463

Source: Author's computations

analyzed. This gives a visual of how the technical efficiency scores are spread across both groups. The result is shown in Fig. 4.

Kernel density estimation was employed to visually compare the distribution of technical efficiency scores between migrant and non-migrant households. This non-parametric technique allows for the assessment of differences in the shape, spread, and central tendencies of efficiency distributions across the two groups. The technical efficiency scores were derived from the stochastic frontier analysis, and the kernel density plots were generated using Stata 17.0. Specifically, the kdensity command was used with group overlay based on migration status, allowing for a smooth comparison of efficiency score patterns. The figure provides insight into the relative performance and variability in technical efficiency among the two household categories.

3.3.2. Logistic regression on the factors that affect migration

The results of the estimates for logistic regression carried out before Propensity Score Matching is presented in Table 7.

The chi-square value of 326.86 and a probability value of 0.000 shows the model has a good fit for modelling the factors that influence migration. The result of the estimates shows that age and education of respondents has negative influence on migration while the number of years spent married and ethnic group has positive effect. The number of years spent with married partner also connotes how long the farmer has been farming and this goes for most of the male respondents as they are given plots of land as soon as they are married, for farming operations. Ethnic group has positive effect because the flooding problems are domiciled in certain communities which are ancestral heritage of such ethnic groups. This is to say that the four local governments areas covered in this study belong to separate ethnic groups in Rivers state, with very few exceptions of foreigners. The rest of the estimates which do not show statistical significance are also depicted in the table.

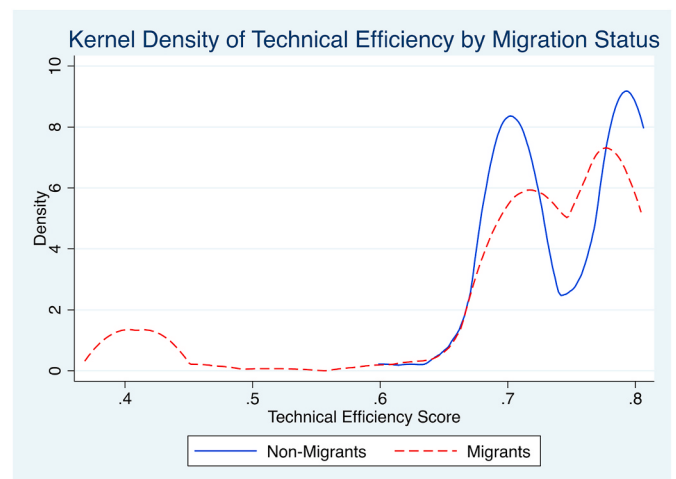


Fig. 4. Density distribution of technical efficiency scores.

Source: Author's computations

Table 7

Logistic regression estimates for factors influencing migration.

Variables	Coefficient	Std. Error	P-values
Family Type	−0.1109	0.5591	0.8430
Household Size	0.0745	0.0549	0.1750
Age	−0.0481***	0.0172	0.0050
Age with Married Partner	0.1279***	0.0406	0.0020
Gender	0.2304	0.7315	0.7530
Marital Status	0.2300	0.2083	0.2690
Religion	0.1407	0.1274	0.2700
Ethnic Group	0.0616***	0.0077	0.0000
Education	−0.5121***	0.1640	0.0020
Constant	−2.9190	1.8618	0.1170
No. of Observation	440		
LR Chi2	326.860		
P-value	0.000		
Log-Likelihood	−138.473		

Source: Field survey, 2024.

3.3.3. Treatment effects of migration on farm's technical efficiency (TE)

The treatment effect analysis using endogenous switching regression started with a test to confirm the presence of endogeneity. To test for potential endogeneity of the migration variable in the technical efficiency model, the control function approach was applied. A first-stage logit regression was estimated using distance to market and ethnic group as instruments, both of which were statistically significant predictors of migration ($\chi^2(2) = 42.37$, $p < 0.001$). The residual from this model was included in the technical efficiency regression. The coefficient of the residual term was statistically significant ($p = 0.000$), indicating that migration is endogenous. Consequently, the relationship between migration and technical efficiency was estimated using an endogenous treatment effect model to address selection bias.

To compare the technical efficiencies of the treatment and control groups, the Logit model of migration participation was first estimated for an endogenous switching regression. The TE results from the stochastic frontier analysis were built into the model and analyzed with TE as outcome variable. The treatment effects were then generated. The results showed the average treatment effect on the treated (ATT), average treatment effect on the untreated (ATU) and the average treatment effect (ATE). These results are presented in Table 8.

The comparison of the technical efficiency of migrants and non-migrants using two-sample t-tests with equal variances, reveals significant differences between the two groups.

The ATT is significant, with a mean difference of negative 3.85 % and also significant for the ATU with 2.01 % value of mean difference. This means that migration indeed, as seen in the technical inefficiency model, affects TE. In essence, due to migration, the TE of migrants reduced by 3.85 percent and their expected TE will increase by 2.01 % if they are not faced with flooding problems and did not migrate. This goes to show that migration affects TE of farms. It also shows that the TE of migrants is lower than that of non-migrants. The ATE is statistically significant with a value of negative 0.39 %.

These results align with a growing body of literature suggesting that migration—especially when environmentally induced—can disrupt agricultural efficiency. For example, Ren et al. [16] reported that rural-urban migration significantly reduced both technical and fertilizer

use efficiency among rice farmers in China. Likewise, in Kosovo, Lesotho, and Burkina Faso, Sauer et al. [27], Mochebelele [31] and Wouterse [32] respectively found that households with migrant labor experienced lower farm efficiency due to reduced on-farm labor, delayed cultivation, and weakened farm management structures. In the Nigerian context, Ayuba et al. [33] confirmed that rural migration adversely influenced household-level crop productivity, particularly in climate-stressed zones, due to temporary abandonment of plots and resource depletion.

Similar patterns are seen across climate-vulnerable regions. Mueller et al. [34] observed that prolonged environmental stress in Pakistan led to increases in long-term migration, which disrupted labor availability and contributed to lower agricultural productivity. Kumasi et al. [35], in a study on small-holder farmers' climate change adaptation practices in Ghana, further concluded that environmentally driven migration often constrains farm capacity and food availability at origin communities. These findings reinforce the notion that recurrent displacement, such as the seasonal migration observed in Rivers State, can negatively impact farm efficiency, not simply due to loss of labor but also due to interruption of production cycles.

For the robustness check of estimates, the Logit model of migration participation was first estimated to obtain the propensity score. The influencing factors of participation in migration were also estimated. The Nearest Neighbour Matching (NN) method was used. The treatment effects estimation using the Nearest Neighbour Matching method with a 1(2) match and bootstrapped standard errors was done. The result provides an insight into the impact of migration on the TE of the farms of treated group versus control group. These results are also presented in Table 7 and show insignificant coefficients for ATT, ATU and ATE. These are not as robust as the ESR estimates.

The estimates obtained from the Endogenous Switching Regression (ESR) model were found to be more robust and statistically significant than those derived from the Propensity Score Matching (PSM) approach, despite both methods being applied to the same dataset. This difference is expected due to the structural advantages of the ESR framework. Unlike PSM, which adjusts only for observable characteristics and is sensitive to sample trimming and matching quality, the ESR model accounts for both observable and unobservable factors that influence treatment assignment and outcome simultaneously. By explicitly modeling the selection process and incorporating the correlation between the error terms of the selection and outcome equations, ESR effectively corrects for endogeneity and self-selection bias. This leads to more efficient estimates, especially in contexts such as this study, where treatment assignment (migration) is driven by exogenous environmental shocks such as flooding, and where differences in exposure severity, geographic vulnerability, or damage extent may not be fully captured by observed covariates. Thus, the ESR estimates are more reliable in identifying the true causal effect of migration on farm technical efficiency. Therefore, interpretation was done with ESR estimates.

4. Summary of findings

The result of the study showed that flooding episodes occurred twelve times in the twelve years under review, in the study area. On the average, eight persons migrated from each household and seven persons

Table 8

Treatment effects of migration on technical efficiency.

	ESR			PSM		
	ATT	ATU	ATE	ATT	ATU	ATE
Technical Efficiency (%)	−3.85 *** (0.0024)	2.01*** (0.0028)	−0.39 * (0.0022)	−3.73 (0.0358)	0.19 (0.0107)	−1.72 (0.0171)

Note: ***, **, * represent 1 %, 5 % and 10 % significance levels, respectively. Figures in parenthesis are std. errors. ESR, Endogenous Switching Regression; PSM, propensity score matching.

Source: Author's computations.

returned home after the flooding episodes. All the respondents migrated during the flooding episodes in the twelve years under review, to several shelters. For the 2022 season, the result showed that out of 246 migrants, 79 % (195) migrated to IDPs, 20 % (48) migrated to family members houses in other communities and 1 % (3) migrated to urban areas. The result of the Translog stochastic frontier analysis showed that the coefficient for seed has a significant positive impact on output. This implies that increasing seed usage increases the output level. The coefficient for labour is also positive and significant. This means that additional use of labour will increase the output level proportionally. The variable for the squared terms showed seed as negative and significant meaning that seed has diminishing marginal returns on output. Squared labour is not significant, so also the interaction between seed and labour. Minimal fertilizer use was recorded in the study area; therefore, it was excluded in the regression.

In the inefficiency model, the variable migrants have a positive and significant coefficient thus showing that migration increases technical inefficiency when compared to their non-migrant counterparts. Indeed, the movement yearly due to flooding episode is associated with increased inefficiency.

The technical efficiencies of farms were calculated from the error terms and result shows that migrants operate at 71.17 % efficiency and non-migrants at 74.63 %. This goes to show that both groups of farmers have room for improvement to achieve efficient production.

The results of the technical efficiency for both groups were compared using endogenous treatment effect and result showed that the average treatment effect on the treated (ATT) is significant, with a mean difference of negative 3.85 % and also significant for the ATU with 2.01 % value of mean difference. This means that migration indeed, as seen in the technical inefficiency model, affects TE. In essence, the TE of migrants reduced by 3.85 % due to migration. Their expected TE will increase by 2.01 % if they are not faced with flooding problems and did not migrate. This goes to show that the TE of migrants is lower than the TE of non-migrants and also, that migration affects TE of farms.

5. Conclusions

Based on the findings from this study, the following conclusions are drawn.

First, the incessant flooding episodes impact negatively on the livelihood of the farmers who earn income majorly from crop production. There is need for this frequent occurrence to be curbed or brought to minimal. Secondly, technical efficiency for both categories of farmers has to be improved upon so as to operate at an efficient level. Part of the reason for these inefficiencies is lack of managerial skills, proper crop combinations and optimum fertilizer and labour use.

Therefore, the study recommends the following.

The government and stakeholder alike should endeavor to initiate and equally execute projects meant to curb flood in these communities affected by flood. The government can build embankments around the river banks to stop the overflow which occurs at certain times of the year. There are practices that have worked in this regard in other parts of the world where flood is an issue. The federal government of Nigeria can emulate this in curbing the menace of flood in Rivers State and other parts of Nigeria where farmers are affected by flooding episodes.

The ministry of agriculture through the Agricultural Development Programmes offices should engage the farmers in educational activities on how to manage their farms, how to combine crops and how to utilize fertilizer and labour for optimum output. These will help improve on farm's technical efficiency.

CRedit authorship contribution statement

Jacinta Nmutaka Umechukwu: Writing – review & editing, Writing – original draft, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data

curation, Conceptualization. **Daniel Bruce Sarpong:** Writing – review & editing, Validation, Supervision. **Akwasi Mensah-Bonsu:** Writing – review & editing, Validation, Supervision. **Ama Ahene-Codjoe:** Writing – review & editing, Validation, Supervision. **Taeyoon Kim:** Writing – review & editing, Validation, Supervision.

Ethical declaration

Ethical clearance, with number ECBAS 065/23–24, was obtained from the Ethics Committee for Basic and Applied Sciences (ECBAS), University of Ghana for the collection of primary data. All participants signed a consent to participate, form indicating their willingness to be interviewed.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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