# LAND EXCHANGE PRACTICE AND TECHNICAL EFFICIENCY OF RICE FARMERS IN NORTH-EASTERN ZONE OF NIGERIA

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## Abstract

In the context of agricultural development, economic growth, and food security in Africa, examining the practice of land exchange holds significant relevance. This study analyses the practice of land exchange and its effect on farmers' performance in Norther Eastern Zone of Nigeria. A multi-stage sampling procedure was employed to select a sample of 400 rice farmers engaged in irrigation farming. The selected farmers participated in structured interviews, providing the necessary data for the study. Descriptive analysis (of the mean) revealed that farmers are engaged in land exchange (16.07%) using two methods: land exchange for agricultural use (or farming purposes) and land exchange for property. Using a logistic regression model, it was found that number of plots, decrease in distance among plots, practice of mechanization, decrease in production costs, and improvement of efficiency were factors influencing farmers to exchange land. The result also suggested that farmers exhibited a high level of technical efficiency, implying that there is room for further enhancement in efficiency through the adoption of advanced technologies and the optimal utilization of existing resources. The beta regression's results indicated that

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land development have a negative effect on technical efficiency, while household size, rented land, and hired labor have positive effects. However, it was found that the practice of land exchange did not affect the level of technical efficiency of rice farmers in the study area, because of the observed limited land market and the high level of crop diversification. Hence, policymakers are advised to define land use rights explicitly and encourage land transactions, such as renting among farmers, selling occupancy rights, and transferring leasehold rights. These measures aim to improve land efficiency and bolster the land market.

**Key words**: Land exchange, efficiency, rice, irrigation, beta regression, Nigeria.

**JEL[7]:** Q1, Q15, R14

## Introduction

Nowadays, farmers are using an increasing amount of fragmented land, which makes distance plot management more laborious and time-consuming. However, it is said that land fragmentation impedes the advancement of mechanical technology and the efficient implementation of irrigation (Demetriou, 2013, Strek et al., 2021). In order to overcome the issue of excessive distance plots into plots as large and regular as feasible, exchange of fragmented parcels (land consolidation) is performed (Len, 2017).

Land consolidation is defined as the voluntary or compulsory reconfiguration of land parcels within a defined area. Its primary objective is to improve the efficiency of land use by establishing larger and more continuous plots that are simpler to handle and cultivate (Holst, 2017). In some cases, land consolidation projects may incorporate land exchange, as a means of achieving consolidation objectives. For example, landowners may voluntarily exchange their fragmented parcels to create larger, more productive holdings. Conversely, land exchange activities can also contribute to the whole process of land consolidation by facilitating the consolidation of land resources in a more efficient manner (Knight, 2010; Asiama, 2019).

A land exchange agreement is generally understood to be a contract in which parties exchange one or more land parcels for better exploitation circumstances (Bullard, 2007). In the context of agriculture, land exchange is more precisely defined as a deal between two or more landowners to exchange lands in order to increase agricultural productivity. As a means to consolidate land ownership for more effective management, land exchange is a crucial tool for managing land tenure. Additionally, it is the method of choice for rearranging and readjusting land ownership with the

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government (Hartvigsen, 2015). The promotion of land exchange has been advocated in various regions as a strategy to tackle the problem of fragmented land holdings (Strek et al., 2021). Before the World War II, Dutch farmers improved their fields by exchanging their properties for one to another in an unregulated manner. According to legal definitions, land exchange is a private initiative that involved a minimum of three landowners (Yimer, 2014).

Klaus and Gershon (2010) highlight that access to land is crucial for household welfare and economic growth in rural areas. However, in developing countries, multiple elements including complex land tenure systems, absence of well-defined land rights, and administrative hurdles limit the use of land and other transactions related to land.

The legal system of several Sub-Saharan African nations stipulates that the state owns all land on behalf of the entire population. So, it is forbidden to sell land, or the land market is prohibited. But land is being exchanged for the cash without any legal documentation of transaction or ownership, nor any public acknowledgement of the terms of sale and purchase (FAO, 2010). It is what the phrase "informal formalization" from Benjaminsen and Lund (2003) refers to. Despite the fact that these transactions seem more frequent and routine, its unable to consider them lawful.

In South Africa, land exchange is a complex issue, deeply intertwined with the country's history of apartheid and the ongoing efforts to address historical injustices related to land ownership. The post-apartheid government has been working on land reform strategies to redistribute land to the historically disadvantaged black majority. This includes land exchange mechanisms as part of broader land redistribution and restitution programs. The process aims to correct the skewed land arrangements that have led to agricultural unproductivity and food insecurity for a significant portion of the population. However, the challenge remains to implement land reform in a way that also promotes food security and nation-building (Lahiff, 2020). In practice, land exchange in South Africa involves legal property transfers where parties exchange ownership over different pieces of land. This can help in rectifying the historical disparities in land ownership. However, it's essential that these exchanges are conducted fairly and transparently to ensure that they contribute positively to the country's socio-economic development (Lahiff, 2020).

Land exchange in Ethiopia is a critical component of the country's agricultural productivity and land tenure security. The Ethiopian government, recognizing the inefficiency of farming fragmented plots, has been encouraging farmers to create larger plots through voluntary land exchange.  Nevertheless, there are no explicit statutes, rules, or directives that govern the process of land consolidation or specify its framework (GIZ, 2022). Moreover, Alemu et al. (2019) reveal a serious problem of comprehensive experience of farmers on land exchange projects. According to report, 68% of the surveyed farmers had never used a land exchange strategy to consolidate their holdings and increase output. The possibility of easier access to irrigated land and optimal farm operations, as well as shorting the distance between the holdings and town facilities are the primary drivers of the farmers engaged in land consolidation projects (Alemu et al., 2019).

In many parts of Africa, especially in Nigeria, smallholder farms dominate the agricultural landscape. Land exchange mechanisms can help consolidate fragmented landholdings, which can lead to improved efficiency through better management and the possibility of mechanization (Giller et al., 2021). Saleh et al. (2022) argue that the persistence of small farmland that characterizes agricultural activity in Nigeria is due to increasing land fragmentation, which reduces the efficiency of small farmers and represents a major challenge for Nigerian agriculture. Since it is widely accepted that the large farmers are generally more economically efficient, competitive, and profitable due to their economies of scale. This implies that land exchange, with its many benefits, may enhance the efficiency of farmers in Nigeria.

Some authors have highlighted the significance of land exchange for economic development. They contend that one of the key elements in ensuring agricultural progress through land usage is land exchange. For example, Len (2017) suggested that in order to create plots that are as large as feasible, the exchange of fragmented parcels aims to solve the issue of distant, or fractured plots. Furthermore, the exchange of land is a crucial instrument for land consolidation that individual farmers employ on their own initiative to increase the productivity of their farms (Hartvigsen, 2015).

Previous research carried out within the designated geographical area have examined various aspects such as the impact of rainfall variability on rice yield (Noel et al., 2020), the evaluation of the Dadin-Kowa irrigation scheme (Hassan et al., 2015), the efficiency of utilizing resources in the cultivation of rice (Barau et al., 1999; Tijjani, Bakari, 2013), and the comparison of technical efficiency among rice farmers under different land administration authorities (Sani et al., 2023). Recent research by Ayoola et al. (2022) has explored the reasons behind land exchange among farmers in the study area. However, this particular study did not provide an explanation of the land exchange process and its impact on the technical efficiency of rice farmers. Mentioned creates knowledge vacuum that required to be filled towards to understanding why farmers are exchanging their land. According to mentioned performed study has the main aim to analyze the land exchange practice and its effects on technical efficiency of rice farmers in Dadin-Kowa irrigation scheme area of Gombe and Borno States of Nigeria.

As specific aims of this study are defined: 1) analyze the practice of land exchange in the study area; 2) identify factors influencing farmers to exchange land in the study area; 3) determine the technical efficiency scores of rice farmers; and 4) assess the effects of land exchange on technical efficiency of rice farmers in the study area.

## Analytical Framework

### *Logistic Regression Model*

To understand the reasons behind farmers' acceptance or rejection of land parcel exchange, a logistic regression method was employed. Actually, whenever the dependent variable has just two values 0 and 1, or Yes and No, logistic regression is used. The model fits data to a logistic curve, to assess the probability of an event occurring, and analyzes the link between several independent factors and categorical dependent variable. Nonetheless, there exist two primary categories of logistic regression models: binary logistic regression and multinomial logistic regression. Binary logistic regression is commonly employed when the outcome variable is characterized by two distinct categories, while the independent variables can be of either continuous or categorical nature. In instances where the dependent variable comprises more than two categories, multinomial logistic regression is utilized. It allows for a broader range of outcomes.

One of the main advantages of using a logistic regression model relies on its simplicity and efficiency, especially in cases where the dataset features are linearly separable. Logistic regression models also provide well-calibrated probabilities when you're not only interested in the final classification, but also in understanding the certainty of the predictions (Sperandei, 2013).

Since the dependent variable in this work is dichotomous, binary logistic regression is then applied.

The model is specified as: $$P_i = \frac{1}{1 + e^{-(\beta_0 + \sum_{i=1}^{m} \beta_i X_i)}}$$

Where, is the probability to accept exchanging the land.

$P_i$ ranges between 0 and 1, while $P_i$ is nonlinearly related to $\beta_0 + \sum_{i=1}^{m} \beta_i X_i$

$L = \ln(\frac{P_i}{1-P_i}) = \beta_0 + \sum_{i=1}^{m} \beta_i X_i$ and $\frac{P_i}{1-P_i}$ is then the odds ratio in favor of exchanging the land. The intercept $\beta_0$ represents the numerical representation of the log-odds favoring the exchange of land if others variables are zero. $\beta_i$ refers to the parameters that need to be calculated or estimated. $X_i$ are independent variables.

If *i* takes any value between 1 and m, for example *k*, $\beta_k$ represents the slope. It quantifies the alteration in L resulting from a one-unit adjustment in $X_k$, in other words, it indicates the extent to which the log-odds favoring land exchange are affected when $X_k$ changes by one unit ($k \in [1; m]$).

## *Technical Efficiency*

As explained by Battese and Coelli (1995), technical efficiency refers to the condition where it is possible to decrease the usage of inputs without causing any adverse impact on farm output. In simpler terms, technical efficiency is about achieving the highest possible output from a specific combination of inputs (Palmer, Torgerson, 1999).

In this study, Stochastic Frontier Production (SFP) is preferred, since it confers the advantage of employing econometric models to estimate production frontiers, which serve as benchmarks for measuring the performance of production units. It also provides a numerical value of performance that is objective, aiding policymakers in identifying performance gaps (Nguyen et al., 2022). The SFP function, as introduced by Battese and Coelli (1995), will be utilized in this study. The function is presented as follows:

$$Y_i = f(X_i, \beta)\exp\,(V_i - U_i)$$

Where, i =1,2,3…*n*, $Y_i$ - Output of the $i^{th}$ firm, $X_i$ - a vectors of inputs, *f(i)* - a suitable functional form, such as Cobb-Doubles or tans-log, $V_i$ - represents random errors that are presumed to encompass measurement inaccuracies associated with the farm, $U_i$ – is a non-negative random error that is assumed to capture the technical inefficiency in production. It is reached by truncating (setting to zero) a normal distribution with a mean value of $\mu_i = Z_i\delta$ and the variance $\sigma_\mu^2$.

Technical efficiency is given by the formula:

$$TE_i = \frac{f(X_i, \beta)\exp\,(V_i - U_i)}{f(X_i, \beta)\exp(V_i)} = \exp(-U_i)$$

Some other important parameters of the model are:

$\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\lambda = {\sigma_u}/{\sigma_v}$ and $\gamma = {\sigma_u^2}/{\sigma^2} = {\sigma_u^2}/{\sigma_v^2 + \sigma_u^2}$ and

$\varepsilon_i = V_i - U_i$. The maximum likelihood estimation (MLE) method is well-suited for estimating the parameters of the stochastic frontier production equation. Hence, the individual technical efficiency (TE) is determined by the conditional mean of $\exp(-U_i)$, considering the distribution of the composite error term, $\varepsilon_i$.

In the process of obtaining the technical efficiency scores, significant changes in the output levels would be indicated by significant values of σ and λ. If the λ term has a value greater than one, this implies that inefficiencies have a greater impact on changes in output compared to random factors. When γ = 0, it indicates that deviations from the frontier are solely attributable to noise. So, the estimates obtained through ordinary least squares (OLS) align with the results obtained through maximum likelihood estimation (MLE). If γ = 1, then all variances can be solely attributed to variations in TE between farms.

***Beta Regression Model***

To determine the effects of different factors on technical, allocative and economic efficiencies, Beta regression model was used. This model offers the advantages of modeling dependent variables that are proportions, rates, or fractions, ensuring that predictions stay within the 0-1 range, and handling heteroskedasticity, which is when the variability of the dependent variable is not constant across levels of an independent variable (Heiss, 2021). The model employed in this study adopts a fully parametric approach, assuming that the dependent variable adheres to a Beta distribution characterized by its density function:

$$f(y;\mu,\varphi) = \frac{\pi(\varphi)}{\pi(\mu\varphi)\pi(1-\mu)\varphi} y^{\mu\varphi-1}(1-y)^{(1-\mu)(\varphi-1)}, 0 < y < 1$$

Where, $\mu$ - the expected conditional mean value of Y, denoted as $\mu = E(Y/X)$, represents the mean of Y given X. Meanwhile, $\varphi$ represents the precision parameter in the model, and $\pi$ is the gamma function.

$$VAR\ (Y) = \frac{V(\mu)}{1+\varphi} = \frac{\mu(1-\mu)}{1+\varphi}$$

To relate the conditional mean $\mu$ to the predictor variables, the conventional beta regression model assumes a relationship between predictors and the response variable, which is denoted by:

$$n\left(\frac{\mu_i}{1-\mu_i}\right) = g(\mu_i) = x_i^T\beta$$

Where, the vector of covariates is represented by $x_i^T$, while $\beta$ denotes the vector of regression coefficients. $g: (0; 1) \rightarrow \mathbb{R}$ is a link function that exhibits strict monotonicity and is differentiable twice. Based on the added flexibility of the link model, four types of functions were used in order to choose the one that yields fit the best. These four functions are:

$$logit: g(\mu_i) = ln\left(\frac{\mu_i}{1-\mu_i}\right) \quad (1)$$

$$cloglog: g(\mu_i) = \ln\{-\ln(1-\mu_i)\} \quad (2)$$

$$probit: g(\mu_i) = \Pi^{-1}(\mu_i) \quad (3)$$

with $\Pi(.)$ is the standard normal distribution function

$$loglog: g(\mu_i) = -\ln\{-\ln(\mu_i)\} \quad (4)$$

The model that minimizes the Bayesian information criterion (BIC) will be selected.

## Methodology

This study utilized a cross-sectional survey approach, employing questionnaires to gather data for analysis. This design also enables a comparative assessment of the technical efficiency of rice farmers across various land administration authorities within the research area. The research was conducted in the Borno and Gombe States of Nigeria, two of the 36 states in country. The favorable land and climate of these two adjacent states facilitate the cultivation of rice.

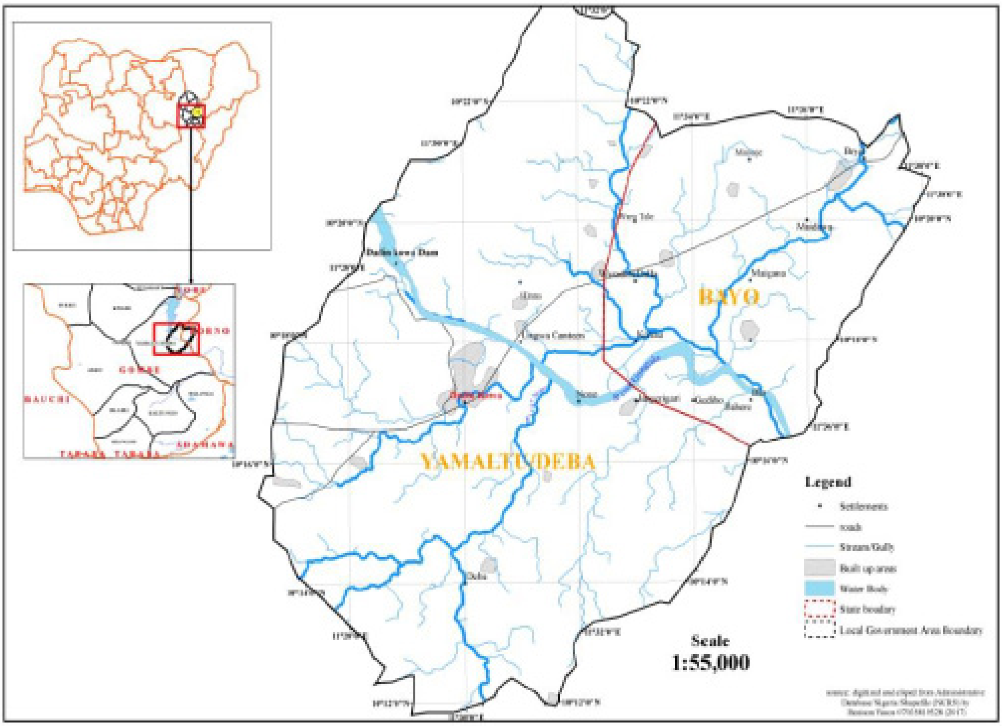
Gombe State is located in the northeastern region of Nigeria, specifically at latitude 10°15’ N and longitude 11° 10’ E. State capital is Gombe. With a overall population of approximately 3,960,100, the state spans at 20,265 km² (NPC, 2022). Borno is located in the northeastern part of Nigeria, specifically at latitude 11° 30’ N and longitude 13° 00’ E. Its capital is Maiduguri. With a population of about 6,111,500, the state spreads at the area of 57,799 km² (NPC, 2022).

The study included the entire population of rice farmers in Gombe and Borno States, which consisted of individuals engaged in the Dadin-Kowa Irrigation Project (DKIP) and those practicing irrigation farming outside of the project (Figure 1.).

The study used the multi-stage sampling method to choose the sample for the research. The selection process involved several stages. In the first stage, one senatorial district was intentionally chosen from each state, based on their proximity to the Dadin-Kowa Irrigation Scheme (DKIS) and the Upper Benue River Basin Development Authority (UBRBDA). Additionally, two Local Government Authorities (LGAs) were purposively selected from each senatorial district. Moving to the second stage, three villages were randomly sampled from each selected LGA. Finally, within each village, respondents were randomly chosen after stratifying them into four land administration authorities: DKIS, Vegetables and Fruits Canning Company

(VEGFRU), National Institute for Horticultural Research and Training and College of Horticulture (NIHORT/CoH), and the local authority (responsible for managing and regulating land-related matters within their jurisdiction).

**Figure 1.** Location of Dadin-Kowa Irrigation Project area and the Irrigation canal in Borno and Gombe States




Source: Upper Benue River Basin Gombe, 2022 (www.gombestate.gov.ng/)

The sample sizes for the different strata were determined through a randomization process, aiming to obtain the required number of respondents for each stratum. Yamane's (1969) formula was applied to the population of 3,691 registered farmers engaged in irrigation farming. It is expressed with next formula: $n = \frac{N}{1+N(e^2)}$

Where, $N$ = real or estimated size of the population; $n$ = sample size; $e$ = level of significance (5% or 0.05). The sample comprised a selection of 400 farmers out of 3,691 listed farmers in the study area (Table 1.).

**Table 1.** Selection plan for the sample size (margin of error 5%)

| States | LGAs | Wards | Villages | Sampling frame | Sample size |
|---|---|---|---|---|---|
| Gombe | Balanga | Telesse | Galangun | 253 | 28 |
| | | | Telesse | 268 | 29 |
| | | | Nasarawo | 248 | 27 |
| | Yamaltu/Deba | Hinna | Hinna | 376 | 41 |
| | | | Dadinkowa | 172 | 43 |
| | | | Yaraduwa | 319 | 34 |
| Borno | Bayo | Briyel | Bayo Briyel | 325 | 35 |
| | | | Tacha Itache | 297 | 32 |
| | | | Gama Jigo | 253 | 28 |
| | Kwaya-Kusar | Kwaya-Kusar | Wandali | 331 | 35 |
| | | | Guwal | 375 | 41 |
| | | | Kwaya-Kusar | 248 | 27 |
| **Total** | **4** | **4** | **12** | **3,691** | **400** |

Source: Field survey data, 2022 (under DKIP-TRIMING project, Gombe, Nigeria).

## Model Specification

### *Logistic Regression Model*

The approach utilized the binary logistic regression model to determine the elements that impact farmer's decision to exchange their land parcels. The model is specified as:

$$P_i = \frac{1}{1 + e^{-(\beta_0 + \sum_{i=1}^{m} \beta_i X_i)}}$$

Where, $P_i$ is the probability to accept exchanging land, $\beta_0$ is the intercept. $\beta_i$ are parameters that need to be estimated, $X_i$ are independent variables, such as: $X_1$= Indigene of the village (yes=1; no=0); $X_2$ = Age (in years); $X_3$=Education (in years); $X_4$ = Household size; $X_5$ = Farm income (in NGN); $X_6$ = Off-farm income (in NGN); $X_7$ = Increase in farm size (1 = yes; 0 = no); $X_8$ = Distance from farm to market (in km); $X_9$ = Distance from farm to home (in km); $X_{10}$ = Irrigation experience; $X_{11}$ = Farming experience (in years); $X_{12}$ = Reduction of plot distances; $X_{13}$ = Practice of mechanization; $X_{14}$ = Reduction of production cost; $X_{15}$ = Improvement of efficiency.

### *Technical Efficiency Model*

The model used is the stochastic production model, specifically the Cobb-Douglas model. It is employed to estimate the score of technical efficiency. It can be expressed as follows:

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \cdots + \beta_6 lnX_6 + V_i - U_i$$

Where,

$l_n$ refers to the natural logarithm with base 10, $Y_i$ represents the total rice output of the farmer measured in kg/ha, $\beta_i$ represents the parameters that need to be estimated, $X_1$ represents the farm size, measured in hectares and it is assumed to have a positive sign, $X_2$ represents the labor used, measured in man-days per hectare, and it is assumed to have a positive sign, $X_3$ represents the planted quantity of seeds, measured in kg/ha, and it is assumed to have a positive sign, $X_4$ represents the used quantity of fertilizer , measured in kg/ha , and it is assumed to have a positive sign, $X_5$ represents the used quantity of pesticides measured in liters per hectare, and it is assumed to have a positive sign, $X_6$ represents the quantity of herbicides used, measured in liters per hectare, and it is assumed to have a positive sign, $V_i$ denotes the random errors, which are assumed to be independently and identically distributed. $U_i$ represents a non-negative random variable related to the production. It is assumed to be independently distributed, and $U_i$ is obtained by truncating (setting to zero) a normal distribution with a mean of Ui is obtained and variance $\delta^2$.

The production inefficiency is presented in terms of factors such as:

$U_i = \sigma_0 + \sigma_1 Z_{1i} + \ldots\ldots \sigma_{10} Z_{10i} + \sigma_{11} Z_{11i}$

Where,

σ represents a vector of unknown parameters that has to be estimated, $Z_1$ represents the farmers' age measured in years, and it is assumed to have a negative sign, $Z_2$ represents the education level measured in years of formal education, and it is assumed to have a negative sign, $Z_3$ represents the rice farming experience, measured in years, and it is assumed to have a negative sign, $Z_4$ represents the household size, which refers to the number of individuals who reside together within a dwelling, and it is assumed to have either negative or positive sign, $Z_5$ represents the number of parcels, and it is assumed to have either positive or negative sign $Z_6$ represents the non-agricultural income measured in NGN (Nigerian Naira), and it is assumed to have either positive or negative sign, $Z_7$ represents the marital status, with "married" coded as 1 and "otherwise" as 0, and it is assumed to have either positive or negative sign, $Z_8$ represents membership in a Community Based Organization (CBO), with "yes" coded as 1 and "no" as 0, and it is assumed to have either a positive or negative sign, $Z_9$ represents the cost of transportation measured in NGN, and is assumed to have a positive sign,

$Z_{10}$ represents rental costs measured in NGN, and is assumed to have a positive sign, $Z_{11}$ represents the costs of water measured in NGN and is assumed to have a positive sign.

***Beta Regression Model***

The model is specified as:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots\ldots\ldots\ldots + \beta_{17} X_{17i} + \beta_{18} X_{18i} + \rho_i$$

With, $Y_i = TE_i$

$\beta_0$ = intercept, the value of $TE_i$, when others variables are null; $\beta_i$ = are the parameters to be estimated; $X_1$= age (years); $X_2$= distance to home (in km); $X_3$= experience (years); $X_4$= off-farm income (in NGN); $X_5$= household size; $X_6$= inheritance (1 = yes; 0 = no); $X_7$= purchase (1 = yes; 0 = no); $X_8$= rent (1 = yes; 0 = no); $X_9$= individual lease (1 = yes; 0 = no); $X_{10}$= gift (1 = yes; 0 = no); $X_{11}$= government allocation (1 = yes; 0 = no); $X_{12}$= land administration service index (LASI), (given by the farmers' perception of the quality of land administration); $X_{13}$= land value (soil quality: 5 = excellent; 4 = good; 3 = average; 2 = poor; 1 = very poor); $X_{14}$= land use (Herfindahl index), (intensity of land use: 1 = intensification of the use of farmland; 0 = otherwise); $X_{15}$= land development (farmers' perception of the quality of physical infrastructures in the study area: 5 = excellent; 4 = good; 3 = average; 2 = poor; 1 = very poor); $X_{16}$= land exchange practice (1 = yes; 0 = no); $X_{17}$= land fragmentation (Simpson's Index), (intensity of land fragmentation: 1 = highest level of land fragmentation; 0 = otherwise); $X_{18}$= hired labor force (in man-day); $\rho_i$ is an error term which is assumed to be independent and identically distributed.

## Results and Discussion

***Land Exchange Practice***

The result of the descriptive analysis of land exchange was presented in Table 2. It showed that farmers had information about the practice of land exchange (66.4%, 60.2%, 71.4%, and 66.2% for DKIS, VEGFRU, NIHORT/CoH, and Local authority, respectively). In the same way, most of farmers affirmed that land was exchanged in their area (50.5%, 42%, 60%, and 54.5% for DKIS, VEGFRU, NIHORT/CoH, and Local authority, respectively). Farmers having information about land exchange suggests their adaptability and willingness to explore different strategies to optimize their land resources. This adaptability reflects their recognition of the potential benefits of land exchange in addressing their specific needs and goals

(Gamal, 2022). From the gained results, 16.07% of respondents have exchanged land in the study area, meaning that few farmers from the study area had certain experience in land exchange process. This finding aligns with the results reported by Alemu et al. (2019), who revealed a serious problem of comprehensive experience of farmers in land exchange, since 68% of farmers interviewed did not have any experience in land exchange practice due to concentration of their land holdings and improving their efficiency.

The practice of land exchange is more important in lands administrated by Local authorities (19.5%), and then in DKIS (17.8%), NIHORT (17.1%), while the VEGFRU shown the lowest importance (9.9%). This means that Land exchange provides opportunities for farmers to expand their operations by acquiring additional land. This expansion allows for increased production capacity, the introduction of new crops, and the ability to implement more diversified farming systems (Len, 2017; Gamal, 2022). However, the practice of land exchange is done informally among farmers, except for land administrated by local authorities, whereby only 6.4% have practiced formal land exchange. Land exchange has been a long-standing practice embedded in local customs and traditions. Informal land exchange methods have been passed down through generations and are deeply rooted in the social fabric of the community (Vincent, 2016).

The land exchange approaches practiced in the study area were land exchange for use (or farming purpose), (13.2%) and exchange of property (2.87%). Land exchange for use is more important in DKIS (16.7%), followed by NIHORT/CoH (14.2%), Local authority (12.9%), and VEGFRU (8.9%). This result showed the importance of land exchange for use in the study area, as presented by Ito et al. (2016) in the case of Japanese agriculture during the agricultural stagnation period in the late 1980s. Then was confirmed the improvement in farmland use efficiency by facilitating land rights transfers from farm households that had ceased farming, or reduced their farm operational size, holding this land temporarily, and subsequently selling or renting it out to farm households that intended to enlarge their farm size. However, exchange of propriety is more important in Local authority (6.6%), followed by NIHORT/CoH (2.9%), DKIS (1.1%), and VEGFRU (1%). The derived results showed that farmers in local lands were very few to exchange their propriety, meaning that farmers did not want to lose the control over their land.

**Table 2.** Land exchange (LE) approaches

| Element | DKIS (%) | VEGFRU (%) | NIHORT/CoH (%) | LOCAL (%) |
|---|---|---|---|---|
| Farmers having information about land exchange | 66.4 | 60.2 | 71.4 | 66.2 |
| Farmers aware of land exchange practice in the study area | 50.5 | 42 | 60 | 54.5 |
| Farmers who exchanged land in the study area | 17.8 | 9.9 | 17.1 | 19.5 |
| **Land exchange approaches** | | | | |
| Land exchange for use | 16.7 | 8.9 | 14.2 | 12.9 |
| Exchange of propriety | 1.1 | 1,0 | 2.9 | 6.6 |
| None | 82.2 | 91.1 | 82.9 | 80.5 |
| **Formality** | | | | |
| Formal | 0 | 0 | 0 | 6.4 |
| Informal | 17.8 | 9.9 | 17.1 | 13.1 |
| **LE rights** | | | | |
| Sell | 0.9 | 0.6 | 0 | 16.4 |
| Farm | 17.8 | 9.9 | 17.1 | 19.4 |
| Develop | 17 | 7.7 | 2.1 | 9.4 |
| Lease | 11.2 | 1.7 | 3.2 | 10.4 |
| Rent | 16.8 | 3.9 | 1.2 | 19.5 |

Source: Field survey data, 2022 (under DKIP-TRIMING project, Gombe, Nigeria).

The major rights related to a land acquired through land exchange is the right of farming (17.8%, 9.9%, 17.1%, and 19.4% for DKIS, VEGFRU, NIHORT/CoH and Local authority, respectively).

### *Factors Influencing Farmers to Exchange Land*

Table 3. presents the analysis of the factors influencing farmers to exchange the land. According to the Nagelkerke R-squared model, 69.1% of the variations in the probability of exchanging land could be explained by the independent variables in the model. This statement indicates that the independent variables included in the model can account for 69.1% of the variability observed in the likelihood of land exchange. In other words, these variables provide a reasonable explanation for the majority of the changes seen in the probability of farmers engaging in land exchange.

**Table 3.** Factors influencing farmers to exchange land

| Variables | B | SE | Wald | P-value |
|---|---|---|---|---|
| Indigene | 0.28 | 0.749 | 0.001 | 0.97 |
| Age | 0.011 | 0.033 | 0.119 | 0.73 |
| Education | -0.154 | 0.176 | 0.767 | 0.381 |
| Household size | 0.008 | 0.045 | 0.031 | 0.861 |
| Number of plots | 0.346 | 0.116 | 8.95*** | 0.003 |
| Farm income | 0.0001 | 0.0001 | 0.202 | 0.653 |
| Non-farm income | 0.0001 | 0.0001 | 0.842 | 0.359 |
| Distance to market | -0.043 | 0.067 | 0.421 | 0.517 |
| Distance to home | -0.046 | 0.119 | 0.147 | 0.701 |
| Experience | -0.019 | 0.038 | 0.232 | 0.63 |
| Irrigation experience | -0.007 | 0.036 | 0.042 | 0.837 |
| Increase of farm size (1) | 20.633 | 4,803.98 | 0.0001 | 0.997 |
| Reduce plots distance (1) | 2.329 | 1.38 | 2.82* | 0.093 |
| Practice of mechanization (1) | 3.803 | 1.393 | 7.457*** | 0.006 |
| Reduce production cost (1) | 3.396 | 1.537 | 4.882** | 0.027 |
| Improve efficiency (1) | 4.7 | 1.249 | 14.154*** | 0.000 |
| Constant | 4.576 | 1.386 | 10.906 | 0.001 |

Source: Field survey data, 2022 (under DKIP-TRIMING project, Gombe, Nigeria).

Note: Chi-Squared statistic = 215.013; p-value = 0.001; Nagelkerke R-Squared = 0.691; -2log likelihood = 152.850; Statistical significance: ***, **, * = significance at 1%, 5%, and 10% respectively.

The findings indicate that the chance of exchanging land was significantly ($p < 0.01$) enhanced by the number of plots. This implies that farmers with many plots might easily come to an agreement to exchange plots in order to maximize their methods of production. Reduction of distance among plots, practice of mechanization, reduction of production costs, and improvement of efficiency, defined as dummy variables increased significantly at 10%, 5% and 1% level respectively, the probability to exchange land in the study area. This implies that farmers were highly aware of the benefits of land exchange. Derived result is more or less in conformity with Akkaya Aslan et al. (2007), who found that farmers are in general motivated to apply the process of land consolidation in order to increase their farm size, to reduce inter-farmer conflicts, to practice mechanization and to implement irrigation system.

### *Percentage Distribution of Technical Efficiency*

As the result of the maximum likelihood estimates of the Cobb-Douglas stochastic production function, the distribution frequency of the predicted technical efficiency is presented in Table 4. The average technical efficiency (TE) for DKIS, VEGFRU, NIHORT/CoH, and the Local authority were found to be 0.88, 0.94, 0.86, and 0.65, respectively. This indicates that farmers in these zones are operating at a high level of technical efficiency. However, there is still room for improvement in the technical efficiency of rice farmers practicing irrigation farming in the study area. By utilizing the available resources and adopting current technological advancements, as well as receiving better extension services, the technical efficiency of these farmers could potentially increase by 0.12, 0.06, 0.14, and 0.35, respectively.

**Table 4.** Percentage distribution of technical efficiency

| TE | DKIS | | VEGFRU | | NIHORT | | LOCAL | |
|---|---|---|---|---|---|---|---|---|
| | Freq | (%) | Freq | (%) | Freq | (%) | Freq | (%) |
| <0.3 | 0 | 0 | 1 | 0.6 | 0 | 0 | 5 | 6.5 |
| [0.3 - 0.5[ | 1 | 0.9 | 1 | 0.5 | 0 | 0 | 12 | 15.6 |
| [0.5 - 0.7[ | 9 | 8.5 | 3 | 1.1 | 3 | 8.6 | 31 | 40.6 |
| [0.7 - 0.9[ | 31 | 29.3 | 28 | 15.4 | 22 | 62.8 | 18 | 23.4 |
| >0.9 | 66 | 61.3 | 148 | 82.4 | 10 | 28.6 | 11 | 14.4 |
| **Total** | **107** | **100** | **181** | **100** | **35** | **100** | **77** | **100** |
| Max | 0.99 | | 0.99 | | 0.99 | | 0.99 | |
| Min | 0.34 | | 0.29 | | 0.68 | | 0.21 | |
| Mean TE | 0.88 | | 0.94 | | 0.86 | | 0.65 | |

Source: Field survey data, 2022 (under DKIP-TRIMING project, Gombe, Nigeria).

***Effect of Land Exchange on Technical Efficiency of Rice Farmers***

With a p-value of 0.0001, the likelihood ratio chi-squares of 56.77 indicated the fitness of the model at the 1% ($p < 0.01$) significant level (Table 5.). Comparing with a model without any predictors, this model fits substantially better. This, however, was insufficient to assess the fitness of the model. When the model is properly specified, the estimators in beta regression are consistent and efficient, according to Smithson and Verkuilen (2006). By the way, the model with the lowest Bayesian information criterion (BIC) values is better than the models with higher BIC values. Four links models (logit, cloglog, probit, and loglog) were estimated until the model with the lowest BIC value was obtained. And then, the coefficients on the predictors and marginal effects (dx/dy) were recorded and interpreted.

The findings indicate that among the eighteen variables examined, four variables were identified as having a statistically significant impact on the technical efficiency of rice farmers in the study area. These variables are household size, rental costs, land development, and hired labor. At a significance level of 5% ($p < 0.05$), it was determined that household size had a significant influence on technical efficiency. When all other factors were held constant, it was observed that a one-person increase in family size led to an immediate 0.26% increase in the value of the technical efficiency. These findings align with previous research conducted by Umeh and Atarboh (2007), as well as Adeshina et al. (2020), which also demonstrated the positive impact of household size on technical efficiency.

**Table 5.** Effects of land exchange on technical efficiency

| Variables | coefficients | z-stats | dx/dy |
|---|---|---|---|
| Age | 0.006 | 1.06 | 0.0008 |
| Distance to home | -0.021 | -1.50 | -0.0025 |
| Experience | -0.01 | 0.007 | -0.0013 |
| Off farm income | -1.49e-07 | -1.13 | -1.76e-08 |
| Household size | 0.022** | 2.10 | 0.0026 |
| Inheritance | 0.078 | 0.29 | 0.009 |
| Purchase | 0.21 | 0.62 | 0.024 |
| Rent | 0.48* | 1.87 | 0.057 |
| Lease | 0.35 | 0.84 | 0.041 |
| Gift | 1.26 | 0.84 | 0.148 |
| Government allocation | -0.38 | -1.52 | -0.045 |
| LASI | 0.37 | 0.78 | 0.043 |
| Land value | -0.014 | -0.08 | -0.002 |
| Land use | 0.033 | 0.11 | 0.004 |
| Land development | -0.56*** | -2.61 | -0.066 |
| LEP | 0.014 | 0.10 | 0.002 |
| LFI | -0.07 | -1.19 | -0.008 |
| Hired labor | 0.15** | 2.04 | 0.018 |
| Constant | -2.68 | -0.94 | - |
| LR Chi2(18) | 56.77 | - | - |
| Prob > chi2 | 0.0001 | - | - |
| Log likelihood | 480.04 | - | - |
| BIC | -840.30 | - | - |

Source: Field survey data, 2022 (under DKIP-TRIMING project, Gombe, Nigeria).

Note: ***, ** and* significant at 1, 5 and 10% respectively. Bayesian information criterion (BIC).

At the 10% level of probability ($p < 0.1$), the results indicated that the rented land was positively correlated and statistically significant. This suggests that renting land improves technical efficiency. More specifically, the technical efficiency score value would instantly rise by 5.7% if rented land was used. Thus, on rented plots, there is no loss in technical efficiency. Farmers who use rented property are forced to adopt suitable production methods in order to offset the high cost of land. The results are consistent with those of Feng (2008), who discovered that rice farmers in rural China produce rice more efficiently when they rent a land. Furthermore, it was observed that households that engaged in land rental exhibited higher levels of technical efficiency compared to households that did not rent land.

The coefficient associated with land development in the study area was found to be negative and statistically significant at a 1% level of probability ($p < 0.01$). This indicates that the farmers' perception of the state of physical infrastructure (irrigation systems, farm storage facilities, processing centers, road, bridge, water supply system, and electricity infrastructure) would result in low technical efficiency. That is to say that one-unit of change in rice farmers' perception of the reliability of infrastructure would result in a6.6% decline in technical efficiency. This result describes the negative effect of the poor physical infrastructure on rice farmers' efficiency. In fact, the land development project that was supposed to boost the irrigation potential of farmers has never been accomplished for many years. This ongoing situation may explain the farmers' bad perception of the state of infrastructure development in the study area, which affects negatively their technical efficiency. However, the result of Adeoye et al. (2017) confirms the fact that technical efficiency is improved by staying in villages with good physical infrastructure.

Hired labor force affects positively the technical efficiency at 5% significance level ($p < 0.05$). An increase in hired labor by one person would result in an instantaneous increase in technical efficiency score value of 1.8%. This means that hired labor contributes to resource use efficiency thanks to the high level of experience acquired by farmers and the technical assistance provided by the DKIS office in terms of training support. The same result was also revealed by Akinbode et al. (2011). From the derived results, it was found that the exchange of land had no significant effect on the technical efficiency of rice farmers in the study area.

## Conclusion and Recommendations

This study examines the practice of land exchange and its effects on rice farmers' technical efficiency in the North-Eastern zone of Nigeria. The results show that farmers are involved in land exchange within the study area, since 16.07% of them have already practiced it. However, the practice of land exchange is predominant in lands administrated by local authorities, and it is mainly done informally among farmers. Land exchange for use (or farming purposes) and exchange of property were the two approaches predominantly employed by farmers by farmers in the study area. According to farmers' point of view, number of plots, reduction of distance among plots, practice of mechanization, reduction of production costs, and improvement of efficiency are the dominant factors influencing them to exchange the land. It was also concluded that farmers were technically efficient, while its general level of efficiency could be enhanced by utilizing current technology and improving the effective utilization of available resources. Farmers operating under the administration of VEGFRU exhibited a higher degree of technical efficiency in contract to individuals operating under DKIS, NIHORT/CoH, and the local authority. However, household size, land rental, and the utilization of external labor positively influence technical efficiency. Contrary to previous, farmers' perceptions of land development have an adverse effect on technical efficiency. Furtherly, derived study results show that the practice of land exchange does not affect the technical efficiency of rice farmers, because of the limited land market and the high level of crop diversification. So, it is advisable for the government to establish clear policies that define the rights associated with land use and facilitate land transactions, such as the sale of occupancy rights, transfer of leasehold rights, or land rental among farmers. This would contribute to strengthening the land market and promoting the efficient utilization of land resources. This study may be extended to the effects of land exchange on efficiency and rural livelihoods of farmers in other irrigation schemes in Nigeria, and even in other Sub-Saharan countries. All the same, this study provided insights into the relationship between land exchange practices and the rice farmers' technical efficiency in the North-Eastern Zone of Nigeria. By examining how land exchange affects farmers' efficiency levels, the research also contributed to a better understanding of the factors influencing farmers to exchange land in the study area.

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