European Journal of Agriculture and Food Sciences
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Technical Efficiency of Rice Farmers Under Public and Private Land Administration in Dadinkowa Irrigation Scheme Area of Gombe and Borno States, Nigeria

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ABSTRACT

This study analyzed the technical efficiency of rice farmers in Dadinkowa Irrigation Scheme (DKIS) area of Gombe and Borno States, Nigeria. Four hundred (400) rice farmers under irrigation farming were selected using multi-stage sampling procedure to provide data by means of structured interviews. Descriptive statistics were utilized to describe the socioeconomic characteristics of respondents, and a stochastic frontier model was employed to assess the technical efficiency of rice farmers. The stochastic production function showed that in DKIS, technical efficiency increases with farm size (0.25) and labor (0.36), while technical inefficiency increases with transportation (0.0011) and rental cost (0.0095) and decreases with education (-0.49). In Integrated Savanna Vegetables and Fruits Canning Factory (VEGFRU), farm size (0.45) has a positive effect on technical efficiency, while transportation cost (0.003) increases the technical inefficiency of rice farmers. In National Institute of Horticultural Research and Training (NIHORT) and College of Horticulture (NIHORT and CoH), technical efficiency is increased by non-farm income (3.3) and decreased by household size (-0.025). Finally, in local land authority, the quantity of seed (0.16) and fertilizer (0.38) increase the technical efficiency, while the technical inefficiency increases with transportation cost (0.0001) and decreases with education (-0.04) and household size (-0.014). The study also revealed that the mean technical efficiencies of farmers were 0.88, 0.94, 0.86, and 0.65 for DKIS, VEGFRU, NIHORT/CoH, and local authority respectively. This means that farmers were technically efficient given the current level of technology under both public and private authorities. Farmers under the land administration authorities of VEGFRU were more technically efficient than DKIS, followed by NIHORT /CoH), and lastly, local authority. The significant role that the DKIS office played in terms of proximity and assistance to rice farmers may help to explain this. The returns to scale were respectively 0.708, 0.421, 0.52, and 0.566 for DKIS, VEGFRU, NIHORT/CoH, and Local authority. This showed that rice farmers operated at the rational stage of production (diminishing return). It was recommended that Government should accelerate the implementation of land consolidation so as to lessen the effect of land fragmentation and to improve the efficiency of rice farmers under irrigation farming, especially in DKIS and VEGFRU, where farm size had significant effect on technical efficiency. In DKIS and Local authority, Government should strengthen formal education among the rice farmers and facilitate the transportation system for moving rice output from farm to market at affordable cost in the study area.

Keywords: irrigation farming, return-to-scale, rice, Stochastic frontier model, technical efficiency.

Submitted: June 23, 2022
Published: January 24, 2023
ISSN: 2684-1827
DOI: 10.24018/ejfood.2023.5.1.523

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I. INTRODUCTION

In developed economies, population growth is less than 1% per year, but in many Sub-Saharan African countries, it is more than 3% per year [1]. In the meantime, since 1970, global food consumption and production have both increased by roughly 2.2% annually, although in developing nations, consumption has increased by about 3.7% and output by about 3.5%. Furthermore, Sub-Saharan Africa (SSA) is the only region in the world where both per-capita food supply and land productivity are declining [2]–[4].For more than half of the world's population, rice is the primary staple food [5], and Nigeria is one of the largest rice markets in Africa, with an estimated 6.4 million tons of rice consumed domestically each year [6]. In addition, one third of Nigeria's rice demand is currently fulfilled by importation due to poor technology adoption rates, low yields, and low productivity. Nigeria's expanding rice demand creates both a food security concern and an economic opportunity for the nation [7]. The low level of productivity in grain production reflects a low level of efficiency [8].

The huge deficit in rice supply in the country has drawn the attention of several successive Nigerian governments. One of the most important interventions in the rice subsector was the establishment of the River Benue Development Authority (RBDA) in 1976 to reduce the country's dependence on rain-fed agriculture [9]. The functions of RBDA were to supply water at a very low fee, ensure proper development of water resources for multipurpose use, construct and maintain dams and irrigation systems, identify all water resources requirements, as well as to construct, operate and maintain roads and bridges that transport farm products to the market [10].

Dadinkowa area was an important zone of rice production due to the essential role of Dakinkowa and Balanga dams [11]–[12]. However, these large irrigation systems have collapsed due to poor maintenance [13]. Nowadays, most farmers build their wells and use motor pumps to get water for their irrigation purposes. In terms of farm resource usage at the farm level, this may indicate significant levels of inefficiency.

According to Norton *et al*. [1], the difficulties in redistributing productive resources across many small farms are the cause of the large variability in crop output. In Nigeria, inefficiency is one of the main reasons for the low productivity of rice production [14]. Moreover, some Nigerian farmers lack adequate knowledge of crop water requirements and access to adequate irrigation services [15]–[16].

Past studies conducted in the study area concentrated on the effect of rainfall variability on rice yield [17]; assessment of Dadinkowa irrigation scheme [18]; resource use efficiency of rice production [19]–[20]. However, these studies did not compare the technical efficiency of rice farmers under different land administration authorities in the study area. Moreover, little is understood about the current extent of resource inefficiency among rice farmers. This has created a knowledge vacuum that needs to be filled in order to improve the efficiency of rice farmers in Dakinkowa irrigation area. It is based on this backdrop that this study aimed at an analysis of the technical efficiencies of rice farmers in Dadinkowa irrigation scheme area of Gombe and Borno States of Nigeria.

Specifically, the study aims to: (1) Describe the socioeconomic characteristics of rice farmers; (2) Identify the determinants of technical efficiency of rice farmers under different land administration authorities; (3) Estimate the scores of technical efficiencies among rice farmers under different land administration authorities; and (4) Analyze the return to scale of rice farmers under different land administration authorities.

II. Technical Efficiency

According to Battese and Coelli [21], technical efficiency occurs when there is a possibility to reduce inputs used without negatively affecting farm output. From the output perspective, technical efficiency evaluates the potential change in output while maintaining a constant level of inputs.

The Stochastic Frontier Production (SFP) function used in this study is defined as follows:

$$Y_i = f(X_i, \beta)\exp(V_i - U_i) \tag{1}$$

where:
Y_i –output of the firm,
X_i – a vector of inputs,
f(i) – is a functional form that is appropriate, such as Cobb-Douglas or translog,
V_i– are considered as random errors that account for measurement inaccuracies (errors) in the farm,
U_i– are random errors that are nonnegative and assumed to account for technical inefficiency in the production.

They are obtained by truncating (at zero) the normal distribution with the mean $\mu_i = Z_i\delta$ and the variance negative.

The ratio of the observed output (Yi) to the associated frontier output (Yi*) is used to define each farmer's technical efficiency (TE). This is given by the formula:

$$TE_i = \frac{Yi}{Yi^*} = \exp(-U_i) \tag{2}$$

Here TE takes values between 0 and 1.

Other key variables in the model include:

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

the cumulative standard normal distribution function is given by π and $\varepsilon_i = V_i - U_i$.

However, to obtain estimates for the stochastic frontier production equation, the maximum likelihood estimation (MLE) method is used. Therefore, given the distribution of the composite error term ε_i, the conditional mean of exp(-Ui) provides the value for the individual TE (i).

Significant values of σ and λ would suggest that there are substantial variations in the production levels. If the term's value λ is greater than 1, it means that the output variations caused by inefficiency are greater than those caused by random variables. γ=0 would mean that the noise alone is entirely responsible for the deviations from the frontier and, in this situation, the model's ordinary least squares (OLS) estimates and the MLE outcomes are similar. γ=1 indicates that all deviations are attributable directly to variations in TE among farms.

III. Methodology

A. The Study Area

This study covered Borno and Gombe States of Nigeria (Fig.1). Gombe State is one of the 36 states that make up Nigeria. It is located in the country's northeastern region, between latitude 10°15′N and longitude 11.10′E. Its headquarters is in Gombe. The State has an area of 20,265 km^2 and a population of around 2,365,000 people. The dry season (November to March) and the rainy season (April to October), with an average rainfall of 850mm, are the two different seasons in Gombe State. Akko, Balanga, Billiri, Dukku, Funakaye, Gombe, Kaltungo, Kwami, Nafada, Shongom, and Yamaltu-Deba are the State's eleven LGAs [22].

Borno is located in northeastern Nigeria at a latitude of 11′N and a longitude of 13.5′E. Maiduguri hosts its headquarters. The state has a 57,799 km^2 land area and a population of about 4,171,104. The State's climate is hot and dry for most of the year in the north, while it is a little bit milder in the south. Rainfall varies between 500 and1,000 mm every year. The climatic conditions of the State are hot and dry for most of the year in the north, while in the south it is a bit milder. The annual rainfall ranges between 500 and 1,000 mm. In the northern region of the State, the rainy season commences in June and lasts until September. While in the South, the rainy season lasts from May to October, with a relative humidity of roughly 49%and 203 mm of evaporation every year [23]. Twenty-seven (27) Local Government Areas make up Borno State, which is divided into three Senatorial Districts: Borno Central, Borno South, and Borno North [24].

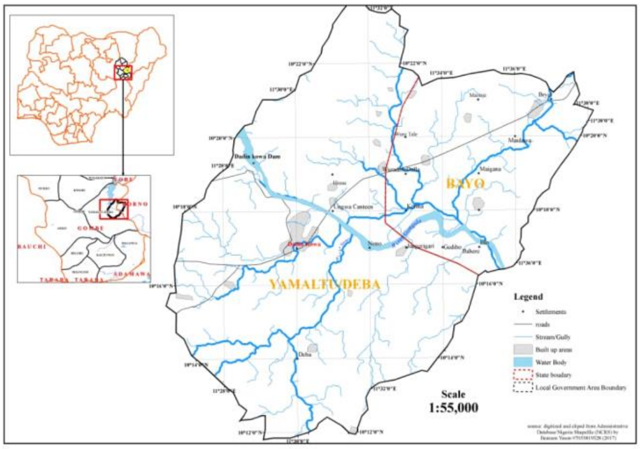

Fig.1. Map showing the location of Dadin-Kowa Irrigation Project area and the Irrigation canal in Borno and Gombe States. Source: Upper Benue River Basin Gombe, 2019.

B. *Study Population and Sample Selection*

The population of the study (Table I) comprised all rice farmers of Gombe and Borno States that are involved in the Dadin-Kowa Irrigation Scheme (DKIS) and those that are not but who are practicing irrigation farming under other public, private, and local land administration arrangements. A multi-stage sampling technique was used for sample selection. Firstly, based on proximity to the DKIS, one senatorial district was purposively selected from each State, and two (2) LGAs were further purposively selected from each of the two senatorial districts. From each of the LGA selected, one ward was also purposively selected based on their proximity to the study area.

Secondly, three (3) villages were selected from each ward using random sampling technique. Finally, from each village, respondents were randomly selected after stratifying them into four (4) land administration authorities: large-scale public DKIS authority; small-scale public/government authority; private land administration authority; and local land administration authority.

To determine the number of respondents for each stratum, the sample sizes for each stratum were determined via randomization using the Taro Yamani [25] formula from a sample frame of 3691 registered farmers practicing irrigation farming. The formula is expressed as follows:

$$n = \frac{N}{1+N(e^2)} \quad (3)$$

where
n– sample size.
N– the real or estimated size of the population.
e– level of significance (5% or 0.05).

The study takes into account a non-response rate of 10%, which is close to the 9% recorded during the last national surveys. This gives a total sample size of 400 randomly selected rice farmers under irrigation system in the study area.

IV. Model Specification

The approach involved in estimating the technical efficiency (TE) scores for the rice farmers was the Cobb-Douglas stochastic production frontier model, described as:

$$LnY\pi=\beta_0+\beta_1 LnX_1+\beta_2 LnX_2+\beta_3 LnX_3+\beta_4 LnX_4+\beta_5 LnX_5+\beta_6 LnX_6+V_i-U_i \quad (4)$$

where
Ln – natural logarithm to base 10,
Y_i – total rice output of the farmer in kg/ha,
β_i – he parameters to be estimated,
X_1 – farm size (hectares),
X_2 – labor used measured in man days per hectare,
X_3 –quantity of seeds planted in kilogram per hectare (kg/ha),
X_4 – quantity of fertilizer used per ha (kg/ha),
X_5 – quantity of pesticides used measured in liters per hectare (litres/ha),
X_6 – quantity of herbicides used measured in liters per hectare (litres/ha),
V_i – Random errors which are considered to be independently and identically distributed,
Ui – A non-negative random variable linked to inefficiency in production.

This is supposed to be independently distributed in such a way that Ui is derived by truncating (at zero) the normal distribution with variance σ^2 and mean Ui.

The inefficiency of production was structured in terms of factors such as:

$$U_i=\sigma_0+\sigma_1 Z_{1i}+\sigma_2 Z_{2i}+......+\sigma_{10} Z_{10i}+\sigma_{11} Z_{11i} \quad (5)$$

where
σ – a vector of parameters that need to be estimated,
Z_1 – age of farmers in years,
Z_2 – education Level, using years of formal education,
Z_3 – experience in rice farming in years,
Z_4 – household size measured as the number of relatives residing together in a house,
Z_5 – number of parcels,
Z_6 – non-agricultural income (Naira),
Z_7 – marital status (married=1, otherwise=0),

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Z_8 – Member of CBO (Community Based Organizations) (1=yes; 0=no),
Z_9 – cost of transportation (Naira),
Z_{10} – rental cost (Naira),
Z_{11} – cost of water (Naira).

V. Results and Discussion

A. Socioeconomic Characteristics of Respondents

The following socioeconomic characteristics of rice farmers were taken into account in this study: age, sex, marital status, education, household size, irrigation farming experience, farming experience, annual farm income, annual non-farm income, number of plots, and farm size.

The results (Table II) showed that 51.5% of respondents fell between the ages of 31 and 45. The respondents between the ages of 18-30 years and 46-60 years constitute 26.3% and 19.2%, respectively, while only 3% were within the age group of 61-75 years. The average age was 38.6 years old. This implies that the majority of respondents were at their productive age. This is an indication that energetic and vibrant individuals are involved in irrigation rice farming in the study area. This result was in line with the findings of Okello *et al.*[26], Tijani and Bakary [19], and Ayoola *et al*. [27], who found that the majority of rice farmers are young and possess the strength required to do the arduous tasks associated with farming.

From the analysis, the majority (92.5%) of rice farmers were males, while 7.5 % were females. This implies that more males are into irrigation farming owing to their labor-intensiveness in rice production.

This result agreed with Odoemenem and Inakwu [28], who reported that men were predominately involved in rice farming due to their ability to cope with the difficult and hard work associated with irrigation rice farming. This result may also be due to the cultural practice of patrilineal headship and Islamic rules as found by Haruna *et al.* [29] and Ofuoku *et al*. [30].

The result of Table II also indicated that the majority (91.8%) were married. This implies that married people are more likely to work in rice farming since they need money to fulfill their financial obligations [5]. Educational status indicated that 33.8% of rice farmers had no formal education and 66.2% of respondents had at least attained primary school. Specifically, 19.5%, 28.5%, and 18.3% had respectively attained primary, secondary, and tertiary education. It could be deduced that the majority of rice farmers practicing irrigation farming were literate and could make use of new technology to improve their production. This may have an impact on the adoption of better farming and irrigation practices [31]–[32].

The average household size is 10.4, with 59.8% having 1–10 members, 34.7% having 11–20 members, and 5.5% having 21–44 members. This result shows that there is a sufficient labor force that will enhance rice production in the study area [33].

The mean average farming experience was 18.9 years. This means that respondents have vast experience in farming. However, the average irrigation farming experience was found to be 11.4 years, with 78.3% of them having irrigation farming experience of 1-15 years, 19.5% having between 16-30 years, and 2.2% having experience of 31-60 years. This implies that farmers were not engaged in irrigation farming in their early years, due to the financial constraints required for irrigation farming [34].

About 45.3% of respondents earned an annual farm income of 100 000-500 000, 35% of the respondents earned between 500001-1000000, 15% earned between 1000001-2000000, 3% between 2000001-3000000, and 1.7% earned an annual farm income of more than 3000000.The mean farm income of N 789924.5 is an indication that the respondents are not all small farmers. This amount may enable farmers to acquire new technologies, as highlighted by Ganiyu et *al.*[35]. However, 10.8% of farmers had no non-farm income, with 37% having non-farm income between 20001 and 400000. The mean non-farm income is N 491358.75. This result showed that farm income is the most important source of income for the respondents [36]. Nevertheless, non-farm income is not only a source of income for the household but also a source of investment fund to boost agricultural productivity [37].

The mean farm size was 0.63 ha, which is in close proximity to the 0.61 ha average farm size for smallholder farmers [38]. Specifically, 64% had a farm size of less than 0.5 ha, 14% had between 0.5 and 1 ha, 17.3% had between 1 and 2 ha, and 4.7% had a farm size of between 2 and 3 ha. The mean number of plots (3.8) is a sign that farmers operate on fragmented lands. This result agreed with the finding of Olarinre [39]. However, the fragmented nature of land systems represents a curb to the establishment of a successful land market, as observed by Dale *et al.* [40], andit consequently impedes the creation and expansion of an overall equitable wealth distribution.

TABLE I: Sample Size Selection Plan

States	LGAs	Wards	Villages	Sampling frame	Sample needed	Sample size
Gombe	Balanga	Telesse	Galangun	253	25	28
			Telesse	268	26	29
			Nasarawo	248	24	27
	Yamaltu/Deba	Hinna	Hinna	376	37	41
			Dadinkowa	172	39	43
			Yaraduwa	319	31	34
Borno	Bayo	Briyel	BayoBriyel	325	32	35
			TachaItache	297	29	32
			Gama Jigo	253	25	28
	KwayaKusar	KwayaKusar	Wandali	331	32	35
			Guwal	375	37	41
			KwayaKusar	248	24	27
Total	4	4	12	3691	361	400

TABLE II: DISTRIBUTION OF RESPONDENTS BY SOCIO-ECONOMIC CHARACTERISTICS (N=400)

Variables	Frequency	Percent (%)	Mean
Age			
18-30	105	26.3	
31-45	206	51.5	
46-60	77	19.2	
61-75	12	3	
Total	400	100	38.6
Sex			
Male	370	92.5	
Female	30	7.5	
Total	400	100	
Marital Status			
Single	33	8.3	
Married	367	91.8	
Total	400	100	
Education			
No Formal	135	33.8	
Primary	78	19.5	
Secondary	114	28.5	
Tertiary	73	18.3	
Total	400	100	
Household Size			
1-10	239	59.8	
11-20	139	34.7	
21-44	22	5.5	
Total	400	100	10.4
Farming Experience			
1-15	189	47.3	
16-30	168	42	
31-45	37	9.2	
46-60	6	1.5	
Total	400	100	18.9
Irrigation farming experience			
1-15	313	78.3	
16-30	78	19.5	
31-60	9	2.2	
Total	400	100	11.4
Annual farm income			
100000-500000	181	45.3	
500001-1000000	140	35	
1000001-2000000	60	15	
2000001-3000000	12	3	
>3000000	7	1.7	
Total	400	10	789924.5
Annual non-farm income			
None	43	10.8	
60000-200000	38	9.5	
200001-400000	148	37	
400001-600000	84	21	
600001-1000000	54	13.5	
1000001-6000000	33	8.2	
Total	400	100	491358.75
Number of plots			
1-4	285	71.3	
5-8	103	25.7	
9-15	12	3	
Total	400	100	3.8
Farm size			
[0.2; 0.5]	256	64	
[0.5; 1]	56	14.0	
[1; 2]	69	17.3	
[2; 3]	19	4.7	
Total	400	100	0.63

Source: Field survey, 2021.

The mean farm size was 0.63 ha, which is in close proximity to the 0.61 ha average farm size for smallholder farmers [36]. Specifically, 64% had a farm size of less than 0.5 ha, 14% had between 0.5 and 1 ha, 17.3% had between 1 and 2 ha, and 4.7% had a farm size of between 2 and 3 ha. The mean number of plots (3.8) is a sign that farmers operate on fragmented lands. This result agreed with the finding of Olarinre [39]. However, the fragmented nature of land systems represents a curb to the establishment of a successful land market, as observed by Dale *et al.* [40], and it consequently impedes the creation and expansion of an overall equitable wealth distribution.

B. *Estimates of Parameters in the Stochastic Production Function*

Table III presents the maximum likelihood estimates (MLE) of the Cobb-Douglas stochastic production frontier model for rice production. The results indicated that there were technical inefficiency effects, as confirmed by the gamma values of 0.62, 0.71, 0.66, and 0.59, respectively, for DKIS, VEGFRU, NIHORT/CoH, and Local authority. These values of gamma were significant at 1% level of probability. The gamma (γ) ratio shows that the variations between the observed and maximal production function output were caused by different levels of technical inefficiency among farmers rather than random variability. Therefore, gamma values of 0.62, 0.71, 0.66 and 0.59, respectively, for DKIS, VEGFRU, NIHORT/CoH and Local authority imply that about 62%, 71%, 66% and 59% of the variation in the output of rice farms, respectively, for DKIS, VEGFRU, NIHORT/CoH and Local authority were caused by variations in the technical inefficiencies of the rice farmers. The coefficients of sigma square (σ^2) were all less than unity and significant at 1% level of probability, except for NIHORT/CoH, which was significant at 5%level of probability. This shows that the specified distribution assumption of the composite error term is correctly fitted and valid.

The result indicated that all of the production function's variables had positive coefficients and were consistent with the a priori expectation, demonstrating that the estimated production function is an increasing function. In DKIS, both farm size and labor had positive and statistically significant coefficients at levels of 5 and 1%, respectively. The coefficient of farm size (0.25) indicated that farm size and output are positively associated. That means that, under the assumption that all other independent variables remain constant, a unit increase in farm size will result in an increase in output level of 0.25. This result is consistent with Laniyan *et al*. [39], who showed that farm size had a positive and significant effect on the output of rice in Oyo State. In the same way, based on the elasticity of labor (0.36), a unit increase in labor will result in an increase of0.36 in farm output. In VEGFRU, the coefficient of farm size (2.82) was statistically significant at 1% level. This means that an increase in farm size of one unit will result in a 2.82 increase in output. The coefficient of quantity of seed and fertilizer were found to be significant at 5 and 1% levels in local authority. This implies that a high yield would be produced by an improved or better seed rate. This result is almost similar to the work of Ezihe *et al*. [42], who found that in Cross River State, a unit increase in seed rate would

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improve rice yield by 0.115. Furthermore, the increased use of fertilizer would increase production, ceteris paribus. The estimated coefficient of the inefficiency model revealed that among farmers under the DKIS: education, transport, and rental costs were found to have a significant statistical effect on rice producers' inefficiency.

The results showed that the estimated coefficient of education (-1.65) was statistically significant at 10% level and had a negative sign for technical inefficiency, which implies that inefficiency decreases accordingly with greater education levels. This means that negative signs of parameters indicate that these related variables improve the efficiency and vice-versa. This finding is in agreement with Ajibefun [43], Ogundari [44], and Akinbode *et al*. [14], who found that education reduces the level of technical inefficiency in Ofada rice farming in Ogun State.

The results on Table III also showed that transportation and rental costs were positive. This implies that an increase in transportation and rental costs will decrease the efficiency of rice farmers. That is to say, transportation and rental costs had negative effects on the ability of the farmers to optimally combine the available inputs. In VEGFRU, transportation costs decrease the efficiency of rice farmers.

In NIHORT/CoH, household size increases the efficiency of rice farmers. This finding is consistent with the findings of Umeh and Ataborh [45], who discovered that as household size increased in Kogi State, technical inefficiency decreased. Non-farm income, on the other hand, reduces the efficiency of rice farmers under NIHORT/CoH land administration. In Local authority, education and household size increase the farmers' efficiency. This result is consistent with the findings of Onyenweaku and Ohajianya [46], who found that education and household size affect positively the efficiency of rice farmers. However, transportation costs decrease the technical efficiency of rice farmers in NIHORT/CoH.

Table IV shows the frequency of distribution of the predicted technical efficiency. The mean values of TE were 0.88, 0.94, 0.86, and 0.65 for DKIS, VEGFRU, NIHORT/CoH and Local authority respectively. This indicates that the technical efficiency of rice farmers under irrigation farming in the study area could be increased by 0.12, 0.6, 0.14, and 0.35 respectively through the utilization of available resources considering the state of technology and better extension services.

The relative analysis of efficiencies among farmers in the study area implies that if the average farmer in the sample was to equalize with the technical efficiency of his most efficient counterpart in DKIS, then the average farmer could achieve a cost saving of 11.1% (that is to say: 1 – (0.88/0.99) or an increase in output. In the same way, in VEGFRU, NIHORT/CoH, and Local authority, the average farmer could realize 5.05, 13.13, and 34.34% cost savings or increase in output, respectively.

TABLE III: MAXIMUM LIKELIHOOD ESTIMATES OF THE PARAMETERS IN THE STOCHASTIC FRONTIER ANALYSIS OF TECHNICAL EFFICIENCY

	DKIS		VEGFRU		NIHORT		Local	
Variables	Coeff	T-ratio	Coeff	T-ratio	Coeff	T-ratio	Coeff	T-ratio
Constant	2.85	11.88***	-4.09	-13.35***	0.55	0.14	2.0	4.81
Farm size	0.25	2.27**	0.45	2.82***	0.52	1.13	-0.08	-0.55
Labor	0.36	2.72***	0.07	1.26	-0.37	-1.33	0.1	0.68
Quantity of seed	0.035	0.67	-0.12	-1.01	0.13	1.45	0.16	2.17**
Quantity of fertilizer	0.06	0.9	-0.01	-0.38	-0.2	-0.94	0.38	3.47***
Quantity of pesticide	0.002	0.17	0.017	1.49	-0.06	-1.09	0.001	0.07
Quantity of herbicide	0.001	0.04	0.014	0.48	0.5	1.14	0.005	1.48
Inefficiency model								
Constant	-3.94	-22.49***	-0.84	-0.2	2.24	3.23	2.0006	4.81***
Age	-0.04	-0.11	-0.056	-0.8	-0.002	-0.29	0.004	1.13
Education	-0.49	-1.65*	-0.0007	-0.0001	-0.99	-1.33	-0.04	-1.78*
Experience	-0.28	-0.73	-0.049	-0.008	-0.002	-0.39	-0.0006	-0.19
Household size	-0.11	-1.26	-0.023	-0.32	-0.025	-1.85**	-0.014	-2.55**
Non-farm income	0.0003	0.25	-0.0001	-0.21	3.3	2.4**	1.4	0.02
Marital status	-0.36	-0.23	-0.71	-0.36	-0.1	-0.99	0.12	1.2
Member of CBO	0.21	0.31	-0.0003	-0.0001	0.11	1.03	-0.017	0.38
Transport cost	0.0011	3.81***	0.003	1.88*	0.0007	1.27	0.0001	4.73***
Water expenditure	-0.0002	-0.2	0.0029	0.96	0.0001	-0.9	2.4	0.55
Rental cost	0.00095	1.78**	0.00032	0.26	0.0003	1.48	7.87	0.41
Sigma-square	0.035	8.75***	0.17	16.19***	0.55	1.69**	0.028	61.16***
Gamma	0.621	4.76***	0.71	4.89***	0.66	3.56***	0.59	2.67***
LR test	28.2		49.9		12.76		27.4	

Source: Field survey, 2021.
Significant at the following levels: *10%; **5%; ***1%.

TABLE IV:%AGE DISTRIBUTION OF TECHNICAL EFFICIENCY

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
	TE		TE		TE		TE	
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, 2021.

A comparable calculation for the least technically efficient farmer reveals an increase in production of 65.65 (that is, 1 – (0.34/0.99), 67.77, 31.31, and 78.78% for DKIS, VEGFRU, NIHORT/CoH, and Local authority respectively to attain the technical efficiency of their respective most efficient counterparts.

The estimated coefficients of the elasticities of production are presented in Table V. The return to scale (RTS) is calculated as the sum of the coefficients and represents the value of overall resource productivity. The returns to scale were respectively 0.708, 0.421, 0.52, and 0.566 for DKIS, VEGFRU, NIHORT/CoH, and Local authority. The values of RTS for DKIS, VEGFRU, NIHORT/CoH and Local Authority were positive and less than one, indicative of the "stage of diminishing return" (stage 2). This means that an increase in the quantity of inputs used to produce rice would cause a less proportional increase in the quantity of output than could be expected. Therefore, rice farmers in DKIS, VEGFRU, NIHORT/CoH and Local authority can increase their output by utilizing more inputs. This result is consistent with the findings of Ambali *et al.* [47] and Aboaba [48], who reported that rice farmers in Ogun State operate at the rational stage of production. It is also the viewpoint of classical economists such as Steuart [49] and Schumpeter [50], who asserted that population growth will degrade soil quality.

TABLE V: ELASTICITIES AND RETURN TO SCALE (RTS) ANALYSES OF PRODUCTION FUNCTION

Variables	Elasticities			
	DKIS	VEGFRU	NIHORT	Local
Farm size	0.25	0.45	0.52	-0.08
Labor	0.36	0.07	-0.37	0.1
Seed	0.035	-0.12	0.13	0.16
Fertilizer	0.06	-0.01	-0.2	0.38
Pesticide	0.002	0.017	-0.06	0.001
Herbicide	0.001	0.014	0.5	0.005
Return to scale (RTS)	0.708	0.412	0.52	0.566

Source: Field survey, 2021.

VI. CONCLUSION AND RECOMMENDATIONS

The study concludes that rice farmers were generally technically efficient in Dadinkowa Irrigation Scheme area of Gombe and Borno States of Nigeria, and that there is potential for improvement in the farmers' technical efficiency subject to the role of irrigation management and land administration authorities in terms of proximity of farmers to adequate farm size and access to improved farm inputs. The determining factors of the farmers' technical efficiency were farm size, labor, education, transportation.
and rental cost, household size, non-farm income, seed, and fertilizer. The farmers' technical efficiency slightly varies between public and private land administration authorities; with private authority being highest, followed by public authorities, and lastly local authority (customary system). The farmers operate at the rational stage of production (diminishing return); and the employment of more inputs will result in less than proportionate increase in their rice output. Hence, the farmers have scope to expand their scale of rice production by using bigger farm sizes, with policies in aid of their access to farm inputs, education, and affordable transportation service.

It is therefore recommended that public and private irrigation management authorities should promote avenues such as land consolidation among farmers in order to increase farm size under irrigation and consequently improve the efficiency of rice farmers in the area. Similarly, access to formal education and affordable transportation system should be improved in aid of moving output from farm to market.

ACKNOWLEDGMENT

We are grateful to the Federal Government, the World Bank and the "Transforming Irrigation Management in Nigeria (TRIMING) project" for grant fund support for this study, under the "Innovative Action Research on Identification and Implementation of Land Administration and Consolidation Approaches to Development of DadinKowa Irrigation Project," in North-Eastern states of Nigeria. Also to the States, Local, Traditional leaders, and rural farmers for their technical and provision of reliable information to support the data for the study. Any opinions, findings, and conclusions, or recommendations expressed in this study are those of the author(s) and do not necessarily reflect the views of any organization.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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