Technical Efficiency of Water Use and its Determinants among Small-Scale Irrigation Farmers in the Lower Niger River Basin

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Abstract

The study examined the efficiency of irrigation water use in selected irrigation schemes under the Lower Niger River Basin Development Authority of Nigeria. Data was drawn on 414 small-scale irrigation farms under the two existing tenure Systems in 7 irrigation schemes located in 7 different Local Government Areas under the Lower Niger River Basin Development Authority in both Kwara and Kogi States of North –Central Nigeria.

The DEA results showed that on the average, substantial overall inefficiencies characterized the farms in both the User Allocation and Farmer Occupier tenure systems. Unlike the situation among the rice farms, however, vegetable and maize farmers under the Farmer Occupier System demonstrated considerably higher levels of efficiency than those in the User allocation systems. The rice farmers under the User Allocation System demonstrated higher sub-vector efficiency of water use than those in the farmer occupier. The reverse was the case for the maize farmers in both systems. For the vegetable farmers, it was a switch of value dominance between the Constant Return to Scale Technical Efficiency (CRS TE) and the Variable Return to Scale Technical Efficiency (VRS TE). The tobit result showed that there were some differences in the manner the included correlates impacted efficiency among the two groups.

1.0 Introduction

The rate at which major rivers and lakes are shrinking around the world calls for urgent attention to safeguard the livelihood of millions of people who depend on these water resources especially for fishing and irrigation. For instance, the Lake Chad in north eastern Nigeria, one of the once largest lakes in the world, has reduced by almost 90% its size over the past 60 years. River Niger, which is the third African largest river, is also rapidly shrinking. With a growing population, it has been predicted that, due to desertification, the Sahara will likely expand farther southward which will increase the pressure on the available water resources. According to the (OECD, 2012) It is projected that between 2000 and 2050, water demand will increase by 55% globally. It is also projected that by 2050, 3.9 billion people are likely to be living in river basins under severe water stress.

Nigeria, with three of its six geopolitical zones located in the savannah, all of which are already water-stressed, shares its own episode in this ongoing water-food demand nexus. Following the sahelian drought of the early 70,s, the FG of Nigerian created 12 RBDAs to develop and manage the water resources of the country amongst other complementary functions, in order to buffer the production risks of farmers especially in key producing basins of the country. Ever since this period it has become very obvious, through the awareness of climate change that water is a limiting factor to agricultural production especially in these drier parts of the country. Since this period also, the allocation and management of water supplies in Nigeria have been predicated upon heavy government subsidies. Land ownership arrangement in these schemes was also altered, leaving behind two major tenure patterns namely the User Allocation and the Famer Occupier tenure systems.

According to The Nigerian Electricity Regulatory Commission (NERC), starting from 2015, 18 out of the 23 power plants in the country are unable to generate electricity due to shortage of gas supply to the thermal plants with one of the hydro stations faced with water management issues. This has led to loss of over 2,000 megawatts in the national grid. This development has an indirect potential of mounting more pressure on the available water resources in the country. To this end, measuring irrigation water efficiency is important as this could be the first logical step in a process that leads to efficient utilization of irrigation

Although there are flurries of literature that explore the analysis of the efficiency of agricultural production in developing countries (Ajibefun 2008; Haji, 2006; Malana and Malano, 2006; Chavas et al.;2005;Abay et.at,2004;Binam et al.,2004;Dhunguma et al.,2004; Binam et al.,2003; Coelli et al.,2002, Wadud and White, 2001) most of them have been conducted with little reference to water use. Among those that have specifically addressed the efficiency of water use are: (Somanathan and Ravindranath 2006; Chebil et. al. 2010; Arun et.al. 2012; Speelman 2008; Frija et. al. 2010; Banerji et.al. 2010; Somanathan et.al. Arun et. al. 2012). This study contributes to the growing literature on water efficiency at the farm levels by measuring not just the overall efficiencies but also the sub-vector water efficiency which enable us to monitor water use in a more specific way. Examining this, under two different institutional settings that are faced with a dawning future of privatization, is a novelty about this work. To the best of our knowledge, this is the first study in Nigeria that will attempt to study this aspect of irrigation system.

Specifically, we undertake to answer the following questions: What are the overall efficiency measures of irrigation resource use? What are the sub-vector efficiency measures of irrigation water? What factors are responsible for inefficiencies among the farmers in both the user allocation and farmer occupier systems?

1.2 DEA Model Description

Data envelopment analysis (DEA) was used in this study. The DEA model could be input –oriented or output –oriented under either the assumption of Constant Return to Scale CRS or Variable Return to Scale VRS specifications .Our study focused on the input orientation because our interest is to analyse how input is used efficiently. According to Coelli (1996), the best way to introduce DEA is via the *ratio* form. For each DMU, a measure of the ratio of all outputs over all inputs could be obtained, such as $u'y_i / v'x_i$, where u is an M x l vector of output weights and v is a K x l vector of input weights. To select optimal weights the following mathematical programming problem is specified:

$$\max_{uv} (u'y_i / v'x_i),$$

$$\text{s.t} \quad u'y_i / v'x_i \leq 1, \quad j= 1, 2,\ldots\ldots\ldots N,$$

$$u, v \geq 0. \qquad (1)$$

The aim is to determine the values of u and v that will maximized the efficiency index of the i-th DMU. The condition is that all efficiency measures must be less than or equal to unity. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this, one can impose the constraint $v'x_i = 1$, which provides:

$$\begin{aligned} &\max_{\mu,v} (\mu, y_i), \\ \text{st} \quad & v'x_i = 1, \\ & \mu' y_j - v' x_j \leq 0, \; j=1,2,\ldots..N, \\ & \mu, v \geq 0, \end{aligned} \qquad (2)$$

Where the notation change from u and v to μ and v reflects the transformation. Using the duality in linear programming, the equivalent envelopment form of this problem is:

$$\begin{aligned} &\text{Min}_{\theta,\lambda} \;\; \theta, \\ \text{st} \quad & -y_i + Y\lambda \geq 0, \\ & \theta x_i - X\lambda \geq 0, \\ & \lambda \geq 0, \end{aligned} \qquad (3)$$

where θ is a scalar and λ , is a N xl vector of constants. This envelopment form involves fewer constraints than the multiplier form (K+M <N+l), and hence is generally the preferred form to solve. The value of θ obtained will be the efficiency score for the i-th DMU. It will satisfy $\theta \le 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU.

An extension of the CRS DEA to VRS model can be made (Banker, Charnes and Cooper(1984). This will permit the calculation of TE devoid of these Scale effects.

This is done by adding the convexity constraint: N1 'λ,=l to equation (3) to provide:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ \text{st} \quad & -y_i + Y\lambda \ge 0, \\ & \theta x_i - Y\lambda \ge 0, \\ & N1'\lambda = 1 \\ & \lambda \ge 0, \end{aligned} \tag{4}$$

Where NS is an Nxl vector of ones.

In order to use the DEA to isolate the issue of water use efficiency, the idea of sub-vector efficiency (of water)

will be introduced. The efficiency of a single input (water) will be calculated by holding all the other vector of inputs constant. (Speelman et. al. (2008), Frija et. al (2010) and Chebil et. al. (2010). Oude Lansink and Silva, 2004; Oude Lansink and Silva, 2003; Oude Lansink et al., 2002; Färe et al., 1994).This is describe in equation 5 below

$$\begin{aligned} &Min_{\theta\lambda} \theta^k, \\ st \quad & -y_i + Y\lambda \ge 0, \\ & \theta^k x_i^k - X^k \lambda \ge 0, \\ & x_i^{n-k} - X^{n-k}\lambda \ge 0, \\ & N1'\lambda = 1 \\ & \lambda \ge 0 \end{aligned} \tag{5}$$

Where θ^k is the input k sub-vector efficiency score of water for farm i. The term x_i^{n-k} and X^{n-k} in the third constraint refer to x_i and X^k with the kth input column excluded, whereas in the second constraint, the terms x_i^k and X^k include only the kth input.

Given the price information of the six explanatory variables namely water, land, labour, fertilizer seed and herbicide, the allocative efficiency (AE) and Economic Efficiency (EE) will be calculated. For the case of VRS cost minimization, the input-orientated DEA model can be obtained .This will involve running the following, cost minimization DEA

$$\begin{aligned} &\min_{\lambda, xi^*} w_i' x_i^*, \\ st \quad & -y_i + Y\lambda \ \ge 0 \\ & N1'\lambda = 1 \\ & \lambda \ge 0 \end{aligned} \tag{6}$$

Where w_i is a vector of input prices for the i-th DMU and x* is the cost-minimizing vector of input quantities for the i-th DMU, given the input prices w_i and the output levels y_i. The total economic efficiency of the i-th DMU will be calculated as the ratio of minimum cost to observed cost.

$$EE = \frac{w_i' x_i^*}{w_i' x_i} \tag{7}$$

One can then calculate the allocative efficiency residually as

AE = EE/TE. (8)

2.1 Definition of variables and Empirical Specifications for the Tobit analysis

Six crops altogether were cultivated in the schemes under both tenure conditions the last season. These are Maize, rice and four vegetables .The four vegetable crops are okra, tomatoes, watermelon and leafy vegetable .Some of the vegetable farmers did not follow the pattern of sole cropping as in the case of the grains. For the purpose of convenience we have grouped together all the vegetable farms in each tenure system in all the schemes. For the DEA analysis of these DMUs; outputs, fertilizer, herbicide, pesticide, and Seed were converted to monetary unit i.e the Naira value. Land was measured in Ha, water in m^3 and labour in Man-day.

The study employed the use of tobit model to study the determinants of inefficiency, because the efficiency measures are censored. This involves the estimation of the equation of efficiency measures and suspected correlates of efficiency (Barnes, 2006; Chavas et al., 2005; Binam et al; 2003;).

The standard Tobit model is defined as

$$y_i^* = x_i\beta + \varepsilon_i \qquad (9)$$

$$y_i = y_i^* \quad \text{if} \quad y_i > 0$$

$$y_i = 0 \quad \text{if} \quad y_i \le 0$$

Where y_i* is the latent dependent variable, y_i is the observed dependent variable, which is the sub-vector efficiency index of water use in this case. x_i is the vector of the independent variables, β is the vector of coefficients, and the ε_i's are assumed to be independently normally distributed: $\varepsilon_i \sim N(0, \sigma^2)$ (and therefore $y_i \sim N(x_i\beta, \sigma^2)$).Maximum-likelihood estimation of the Tobit model can therefore be calculated.

We need to briefly point out the little difference in the variables included in the tobit analyses of the UAS and FOS. It was observed that in all the three categories of farmers we identified under the UAS, the number of female farmers was so little that we did not include the variable SEX in the analysis because of the error of autocorrelation. We also struck out fertilizer use from the analysis because all the farmers used fertilizer in the UAS. In the FOS, however, some of the farmers did not use fertilizer while a substantial number of them were female. Political Party (PLP) and position in the society (POS) were included in the UAS data to determine whether or not fertile plot allocation to individuals was done with bias. These were, however, not included in the FOS data.

The variables included in the FOS tobit analysis are: Age of the farmer (years), household size, education (number of years in school), farmers experience (years), irrigation times (number of times water was applied to plot), farmers' political party,(1 if political party is PDP and 0 otherwise), position in the society (1 if farmer is a Chief/Religious Cleric and 0 otherwise),both to capture bias in fertile plot allocation. Membership of Water User Association (1 if farmer is a member and 0 otherwise) to capture closeness of farmers to RBBD officials, which may also influence fertile plot allocation, Extension visit to capture whether or not farmers received farm training for better performance. Non-farm income to capture ability of farmers to finance the farm expenses. The difference in the variables included in the tobit analyses of the FOS is that political party (PLP) and position in the society (POS) were not included. Rather fertilizer use (1 if farmers used fertilizer and 0 otherwise) and SEX (1 if male and 0 otherwise) were included. These are repeated in table 1 of the appendices. The models for the UAS and FOS are empirically specified as follows:

$$Y_{UAS} = \beta_0 + \beta_1 HHS + \beta_2 EDU + \beta_3 EXP + \beta_4 WUA + \beta_5 EXT + \beta_6 IRT + \beta_7 PLP + \beta_8 POS + \beta_9 NFI \qquad 10$$

For the FOS the specification is:

$$Y_{FOS} = \beta_0 + \beta_1 SEX + \beta_2 HSH + \beta_3 EDU + \beta_4 EXP + \beta_5 WUA + \beta_6 EXT + \beta_7 IRT + \beta_8 FRT + \beta_9 NFI \qquad 11$$

Where Y in each case is the censored sub-vector Technical Efficiency of water and the dependent variables are as defined in table1 in the appendices.

2.4 Sampling and Data

Plot –level irrigation water use estimation and subsequent household interview were carried out in the chosen schemes. The sampling procedure was a multi-stage stratified sampling. The first stage is the purposive selection of two States in Northern Nigeria, namely: Kwara and Kogi States which are located in the North Central. The sites were chosen along the northern gradient of the country to account for the drought-prone and arid nature of this agro-ecology and the prevalence of irrigation practices. Public sector irrigation in these two States was controlled by the Lower Niger River Basin Development Authority (LNRBDA). The irrigation schemes under the jurisdiction of the LNRBDA made use of the River Niger and its tributaries for the supply of water. The next stage was the purposive selection of 4 irrigation schemes located in 4 different local Government Areas (LGAs) from each State .This amount to 8 schemes in all, though information in one of the schemes was not complete. The last stage was the random selection of farmers from each of these schemes among the two types of tenancy arrangements that existed in the schemes. These were drawn from the list of the farmers who were registered with the River Basin Development Authourities (RBDAs) in each of the schemes. A selection of 269 farms from the UAS and 145 farms from the FOS was made. This amounted to 414 farms in both.

To estimate water consumption, we adapted the method of Banerji et. al. (2010) and Baljinder et.al.(2010).They computed Irrigation water-use for each farm by estimating the monthly irrigation hours and multiplying it with the volume of water drawn out per hour by the motorised pumps based on the capacity of the pump .We used the following formula to arrive at the quantity of water farmers consumed: Q_{water}=It x Pc. Where, Q_{water} is the total quantity of water used by farmers throughout the season. It is the total number of times irrigation was done before harvest (hours) i.e the number of hours each day multiply by the total numbers of days. Pc is the Pump capacity (liter/hour). Q_{water} was later converted to the m^3 equivalent. In each day of irrigation, records of time irrigation started and ended were taken by the irrigation officials to know the number of hours spent per irrigation period. Pump capacity and record of hours spent in pumping water were taken by the irrigation officials in each of the schemes. This was what we used in our water use estimation.

The data collection was divided into two periods namely, the plot level data collection which enabled us to reasonably estimate the amount of water the small farmers used by direct pumping. The second is the household survey which was carried out after harvest. Field level data collection started in late December 2013 at the beginning of the irrigation season and ended in March ending/early April 2014 after all crops were harvested. During the interview, information was gathered on the irrigation schemes included: household characteristics, farm non-farm activities, quantities and costs of inputs used in production (capital, variable and overhead), volume and value of output, the quantity of water consumed and water demand characteristics and irrigation practices.

3.0 Results and discussions

3.1 Descriptive Statistics

The basic summary statistics of the variables used in the DEA analysis are presented in tables 2a-2c.Talking about water, which is our main target, average water use for the vegetable farmers under the user allocation systems was 1722m^3 and 1174 m^3 for farmers under the farmer occupier system .Average water use for maize farmers under the user allocation system was 1561m^3, and 1366 m^3 in the farmer occupier system. Finally for the rice farmers, average water use under the user allocation system was 2038 m^3 and 1501m^3 under the farmer occupier system. Water use for all the crops in the user allocation system was observed to be greater than what obtained for any of the crop in the farmer occupier system.

The farmers under both systems did not have any restrain to water use under any circumstances from the authority .Time spent in pump operation was determined by the capacity of farmers to fuel the pumps and run it for several hours .The farmers under the user allocation systems are financially well-off than those under the farmer occupier and therefore has capacity to pump water for more length of time. This category of people just come, gets allocation and hand over to labourers. They only come for supervision especially during fertilizer application and harvest. Land size in the user allocation for each crop was observed to be greater than land size under the farmer occupier. For all the crops, apart from rice, labour use was greater in the user allocation than in the farmer occupier systems. The amount spent on fertilizer, chemical and seed were greater in the User Allocation than in the farmer occupier systems for the vegetable crops. For maize, the quantities of these were greater in the user allocation than in the farmer occupier. However, in the rice farms, chemical and seed were greater in the Farmer occupier than in the User Allocation while fertilizer use was higher in the user allocation than the Famer occupier system.

3.2 The DEA Results

Both the CRS and VRS specifications under the input orientation of the DEA models were calculated to get the technical efficiencies. In a second step, the sub-vector Technical Efficiency of water under CRS and VRS were calculated to enable us monitor how efficiently water was used in the chosen schemes. The program DEAP (Coelli, 1996) was used in these analyses. Separate analyses of these were done for each crop identified in all the schemes, under the two major tenancy conditions that prevailed by merging farms that cultivated the same crop together in all the schemes.

The results of the analyses as shown in tables 3a-3c, revealed that considerable technical inefficiencies occurred among the irrigation farmers in both tenancy systems for all the crops. For all the crops, some of the farms considerably attained full CRS TE and VRS TE in both systems. It was observed, however, that CRS TE was lower than the corresponding VRS values in all the cases.

The sub-vector efficiency of water under both CRS and VRS are quite lower than what obtains in the overall efficiency scores. This suggests that farmers were less efficient in the use of water than in the use of overall input. This might be due to the lack of policy incentive, as a result of the water subsidy that should have encouraged farmers to use water more efficiently. It is possible that this may improve in the coming years of privatization or when government decide to metre out irrigation water rather than on a per hectare seasonal charge that presently exists in all the RBDAs. For the rice farms, the efficiency values under the FOS are observed to be lower than what obtains under the UAS. This result suggests that rice farmers under the UAS demonstrated a moderately higher level of technical efficiencies in the use of overall inputs and especially water, which is our main concern.

From these analyses, it can be seen that on the average, substantial inefficiencies characterized the farms in both systems. However, unlike the situation among the rice farms, vegetable and maize farmers under the Farmer Occupier system demonstrated considerably higher levels of efficiency than those in the User allocation systems. This may seem to contradict expectations about the performances of these groups. It would be logical to assume that in all the three category of crops identified among the two systems, farmers who are directly closer to the government should demonstrate higher levels of performance. It all depends on the irrigation pedigree of each of the farmers that constitute these groups. It is possible that there might be switching of systems among some of these farmers so that technologies that exist in one group is not strange to the other, since there is no barrier to exit or entry except for those who were not able to get allocation under the User Allocation System. Or due to the closeness of interaction among these farmers exchange of ideas might be commonplace.

Since the descriptive analyses revealed that farmers under the user allocation that planted the three categories of crops used higher quantity of water than their counterparts in the farmer occupier system, one would expect that sub-vector water use efficiency should be higher under the farmer occupier in the three cases. However, rice farmers under the user allocation demonstrated higher sub-vector efficiency than those in the farmer occupier. The reverse is the case for the maize farmers in both systems. For the vegetable farmers, it is a switch of value dominance between the CRS TE and the VRS TE. This is because increasing or decreasing water quantities applied to crop does not necessarily result in a directly proportional change in productivities. Others factors possibly responsible for this result have been explored in our tobit analyses. But it is of note that in terms of water use, both groups need to be more disciplined.

3.4 Determinants of inefficiency

Having conducted the sub-vector DEA analysis of water use, the next step is the estimation of the factors suspected to be correlates of efficiency on the sub vector estimates. Tables 5a and 5b display the tobit analysis result of the three categories of crop as pooled from the seven irrigation schemes of the two tenure systems.

First is the result of the rice famer under the user allocation scheme. The result of the tobit analysis for the pooled data showed that only five out of the 10 variables were significantly related to sub-vector TE under VRS in the UAS. These are age, household size, WUA, extension service and income from non-farm activities. All these were significant according to their levels as seen in the table Under the CRS, only two were significant, these were age and livelihood activities. The negative significance of age with sub-vector efficiency revealed the effect of ageing farmers on productiveness especially in irrigation farming which is more demanding in terms of physical strength. Household size which was a proxy for household labour use impacted positively on efficiency, as expected this emphasize the importance of labour-intensive nature of irrigation farming. Membership of water user association also impacted positively on efficiency .This means that there was good cooperation among this rice farmers in taking decisions that assisted them in their individual performances. Income from non- farm activity was highly and positively significant with efficiency. This showed that financial buoyancy has a good impact on the farmers' performance.

For the maize farm in the UAS four variables altogether were significant under the VRS while two of these were significant under the CRS model. Household size and Extension service were positively significant with efficiency. Just like in the case of the rice farms, the impact of extension agents was also relevant in terms of the farmers' efficiency; perhaps extension agents concentrated visits on this group because they were directly under government. Unlike the situation among the rice farmers, the negative impact of WUA reveal the weak nature of water User Association in the schemes and these calls for effective coalition of a virile WUA. This is because WUA also has significant roles to play in irrigation management in any nation in terms of scheduling, fee recovery, facility maintenance etc. Position in the society was negatively significant, meaning that farmers did not get allocation based on their position in the society.

For the vegetable farmers in the UAS seven variables altogether were significant in both models. These are age, household size, education, experience, WUA, position in the society and income from nonfarm activities. Age was negatively significant in the VRS model, showing the negative correlation of physical strength with efficiency which is consistent with the findings of Wadud and White (2000) and Binam et.al. (2003).Household size was negatively significant in both models. This may be attributed to the fact that farmers did not make use of family labour in a productive way some of the household members may be underage children who were not old enough to perform farm operations and other may be adult dependants who had little to contribute to farming operation, Experience was positively significant revealing that older and more experienced farmers have more knowledge about irrigation activities. Education was positively significant with efficiency which stressed the importance of formal education in quick adoption of new technology or training received by farmers. Experience had a negative impact with efficiency, meaning that the number of years spent as an irrigators do not automatically amount to ability to improve productiveness especially in the midst of factors which are totally beyond the control of the farmers. Once the basic knowledge of cultivation is in place, it is no longer automatic that a farmer with 20 years experience will perform better than a farmer with just 5 years irrigation experience. Though we expect experience to be positive.WUA, just like the case of rice and maize farmers are negatively significant so also is position in the society, non-farm activities is positively significant with efficiency to stress the role financial buoyancy plays in farm productiveness.

In the maize tobit analysis, five variables in both CRS and VRS were significant .These include extension service, fertilizer use, education, gender, and income from non-farm activities. Education demonstrated a positive impact on efficiency, it revealed that educational level was high among the group of maize farmers and hence readiness to adopt farm practices that boosted productiveness. Extension service was significant but negatively impacted on efficiency. This may be because this group did not receive adequate extension training from extension agents or that visitation did not produce the desired outcome. Fertilizer use negatively impacted efficiency but was expected to have positive sign. This may be directing attention to the degradations of the soil in the place. The need to stay near water source necessitated that the farmers make use of available land space along the river flood plain which might result in over-cultivation and application of micro-doses of fertilizer may not really solve the problem of the declining fertility. SEX was positively significant, revealing the importance of both male and female in irrigation business unlike the perceived gender inequality experienced in the UAS. Finally, income from non-farm activities impacted negatively on efficiency .Perhaps this group did not really use this livelihood income to finance their irrigation farm.

In the FOS tobit analysis for the rice farmers, five variables were significant in both the VRS and CRS models. These are age, fertilizer, sex, extension and household size. Age was negatively significant with efficiency, corroborating the inverse relationship between physical strength and productiveness of the farmers. Fertilizer impacted positively on efficiency, this is because a good number of the farmers in this group used fertilizer and hence boosting the soil fertility. Sex also impacted positively on efficiency. This is due to the fact that female farmers played a prominent role in irrigation activities in this group unlike the UAS where female participant was very minimal. Extension impacted negatively on efficiency due, perhaps to dearth of extension visits to this group or that training received was not adopted gainfully. Household size has a positive relationship with efficiency. Majority of that group made use of household labour in their irrigation activities.

Among the vegetable farmers in the FOS, six variables were significant with the level of efficiency. These are age, experience, education, irrigation times, fertilizer and non-farm activities. The negative sign of age signified that efficiency declined with the degenerating farmers' strength. Experience was positive with efficiency, implying that the length of years spent as an irrigator is also important in the farmers' performance such as crop choice, timeliness, of operation, etc. Among this group, positive significance of education with efficiency showed that farmers in this group were adopters of new technology. Dhungana et al (2004) found a similar result of positive impact of education on efficiency in the Irrigation activities of the district they studied. Fertilizer impacted negatively on efficiency, a result that is contrary to expectation. This might be due to the fact that this group used fertilizer in very small quantities, the effect of which was not significant enough to ward of the effect the declining soil fertility. Finally income from non-farm activity which is an evidence of the financial ability of the farmers impacted positively on efficiency. This means that farmer with high financial endowment performed well in the irrigation business. In the maize tobit analysis of the FOS five variables were significant. These are Farmers' educational level, extension service, fertilizer, sex and non-farm income.

4.0 Conclusion and Recommendation

The study employed the use of DEA to measure the overall technical efficiencies of dry season irrigation farmers in the Lower Niger River Basin Development Authority, under the VRS and CRS specifications, among irrigation farmers operating under two different tenure conditions. To isolate the issue of water more specifically, the sub-vector technical efficiency was calculated for the farmers in each of the tenure system, the User Allocation System and the Farmer Occupier System .Tobit analysis was later conducted to identify the determinants of inefficiencies among these groups

The tobit analyses revealed the factors responsible for the inefficiencies among both groups of farmers in the FOS and UAS. Considering the uneven significant levels of these variables with efficiency, evidences are enough to establish that there were differences in the performance of the two settings. However, the dearth of female farmers in the UAS is regrettable. We suggest that female farmers should be encouraged to participate in irrigation farming for better rural development. We also suggest that levels of perceived insecurity of property right among farmers in the UAS should be minimized by the extension of years of temporary ownership of land beyond a season.

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Appendices

TABLE 1: Definition of variables for the tobit analyses

Variable Names	Description	UAS	FOS
HSH	Household size :Number of persons in the household	√	√
SEX	Sex of household head (dummy):1 if male and 0 otherwise	X	√
EDU	Education :Years spent in school	√	√
EXP	Experience :Number of years spent as an irrigation farmer	√	√
IRT	Irrigation times : Number of times irrigation was done	√	√
WUA	Water User Association :1 if farmer is a member or 0 otherwise	√	√
EXT	Extension: Number of visitation by Extension Agents.	√	√
PLP.	Political party: (1 if PDP member or 0 otherwise	√	X
POS	Position in the society (1 if farmer is a cleric/chief/leader or 0 otherwise	√	X
NFM	Nonfarm income (Naira):amount earned from nonfarm activities	√	√
FRT	Fertilizer (Dummy) 1 if farmer used fertilizer or zero otherwise)	X	√

√ represents "included" and X represents "not included"

Tables 2: Descriptive statistics of the variables used in DEA analyses

	User Allocation system						Famer occupier system					
	Rice: N=125		Maize :N=89		Vegetable :N-45		Rice: N=62		Maize: N= 38		Vegetable N=45	
Variables	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev .
Output	3786	1388	4095	1158	157588	71833	3503	1383	3029	1109	107274	49769
Water	2038	415	1561	563	1722	830.	1502	558	1366	534	1174	449
Land	1.38	0.53	1.73	0.54	1.09	0.76	1.16	0.51	0.68	0.35	0.70	0.33
Labour	38	11	45	10	49	19	42	10.60	41	12	38	10
Fertilizer	168	55	79	37	9544	6612	117	59.71	58	48	4696	5152
Herbicide	3.4	1.18	3.7	1.18	4159	2227	3.69	1.20	1.63	1.41	2025	1667
Pesticide	2.91	1.28	4.15	0.94	3663	1954	3.80	1.08	1.36	1.24	3373	2113
Seed	41	11	47.25	10	6159	2589	43	13.07	44	10.59	5096	1639

Table 3: Technical efficiencies indices for crops in both systems

	User Allocated Tenure System: No of farms						Farmer Occupier Tenure System: No of farms					
	Rice: N=125		Maize :N=89		Vegetable :N-45		Rice: N=62		Maize: N= 38		Vegetable N=45	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
0-10												
10-20												
20-30												
30-40												
40-50							06					
50-60	12				02	01	11	03				
60-70	05	03			06	03	06	06				
70-80	17	10	18	04	06	05	09	08	03	02	02	02
80-90	38	26	35	13	06	06	08	06	03	02	04	04
90-100	36	44	18	50	15	08	06	03	10	06	17	16
100	17	42	18	22	20	32	16	36	22	28	22	23
Mean	0.85	0.92	0.88	0.95	0.89	0.93	0.77	0.90	0.95	0.97	0.95	0.96

Table 4: Sub-vector technical efficiencies indices for crops in both systems

	User Allocated Tenure System: No of farms						Farmer Occupier Tenure System: No of farms					
	Rice: N=125		Maize :N=89		Vegetable N-45		Rice: N=62		Maize: N= 38		Vegetable N=45	
	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS	CRS	VRS
0-10												
10-20												
20-30	02						07					
30-40	18				12	09	21	03	01		01	01
40-50	21		05		13	10	07	06	04	05	04	01
50-60	28	06	22		09	10	12	10	09	09	13	04
60-70	35	38	15		14	10	03	11	08	07	09	03
70-80	15	41	10	03	02	06	06	08	07	06	04	09
80-90	04	30	12	03	03	06	01	10	03	02	08	
90-100	01	06	18	10	01	01	04	09	04	02	05	25
100	01	04	07	22	01	03	01	05	02	07	01	02
Mean	0.57	0.75	0.74	0.95	0.55	0.60	0.50	0.72	0.68	0.70	0.69	0.86

Table 5a: Tobit results for User Allocation System

Variables	RICE: n=125				MAIZE: n=89				VEGITABLES: n=55			
	VRS		CRS		VRS		CRS		VRS		CRS	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
CONST.	0.83^{a}	0.11	0.78^{a}	`1.66	1.02^{a}	0.26	0.87^{a}	0.19	1.09^{c}	0.618	0.687	0.482
AGE	-0.05^{a}	0.01	-0.08^{a}	0.02	-0.01	0.003	-0.002	0.002	-0.005^{b}	0.003	-0.001	0.002
HSH	0.009^{c}	0.005	0.002	0.008	0.02^{c}	0.11	-0.001	0.008	-0.019^{c}	0.01	-0.018^{b}	0.008
EDU	0.01	0.002	-0.001	0.003	-0.004	0.004	-0.003	0.003	0.0075	0.006	0.015^{a}	0.005
EXP	0.002	0.003	0.001	0.005	-0.007	0.008	-0.007	0.006	-0.018	0.049	-0.016^{b}	0.006
IRT	-0.02	0.004	-0.003	0.006	-0.01	0.009	-0.004	0.007	-0.004	0.02	-0.0008	0.17
WUA	0.03^{c}	0.017	-0.01	0.03	-0.08^{b}	0.04	-0.06^{b}	0.03	-0.068	0.05	-0.07	0.039
EXT	0.04^{b}	0.02	0.0007	0.02	0.07^{c}	0.38	0.055^{b}	0.027	0.051	0.051	0.0085	0.039
PLP	-0.03	0.02	0.02	0.03	0.04	0.04	0.007	0.028	-0.018	0.049	-0.04	0.038
POS	-0.02	0.017	0.02	0.03	-0.08^{b}	0.04	-0.03	0.03	-0.088^{c}	0.050	0.063	0.039
NFI	$3x10^{-7c}$	$8x10^{-8}$	$3.8x8^{-7c}$	$1.2x8^{-7}$	$5.4x10^{-8}$	$2.7x10^{-7}$	$4x10^{-8}$	$1.9x10^{-7}$	$1.8x10^{-7}$	$2x10^{-7}$	$3x10^{-7c}$	$1.6x10^{-7}$
Sigma	0.09^{a}	0.005	0.13^{a}	0.008	0.16^{a}	0.01	0.12^{a}	0.009	0.17^{a}	0.016	0.13^{a}	0.013
LL	127.52		75.42		32.96		61.18		18.66		31.79	

(i) a ,b and c represents significant at 1%, 5%, and 10% respectively
(ii) SE, HSH, EDU, EXP, IRT,WUA, EXT, PLP, POS, NFI, LL are respectively Standard error, household size, Educational level, Experience, No of times irrigation was carried out, membership of Water User Association , Extension services, Political party, Position in the society, Income from non-farm activities and Log-likelihood

Table 5b: Tobit result for Farmer Occupier System

bles	RICE: n=62				MAIZE: n=38				VEGITABLES: n=45			
	VRS		CRS		VRS		CRS		VRS		CRS	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
T.	0.763^{b}	0.333	0.537	0.366	0.78	0.333	0.621^{b}	0.30	0.064	0.411	0.588	0.573
	-0.01^{b}	0.004	0.009^{b}	0.0044	-0.004	0.0036	0.0045	0.0032	-0.005	0.0025	-0.0030	0.036
	0.02	0.016	0.05	0.017	0.0093	0.0184	0.019	0.017	0.009	0.007	-0.0006	0.01
	0.002	0.007	-0.005	0.0081	0.012	0.0073	0.016^{b}	0.007	0.01	0.005	0.003	0.0064
	0.005	0.006	0.11^{c}	0.007	0.026	0.0167	0.018	0.015	0.013	0.005	0.0087	0.0075

0.005 0.01	0.002 0.012	-0.0127 0.0124	-0.009 0.01	0.027 0.015	0.0031 0.02
0.0499 0.048	0.001 0.053	0.066 0.060	0.072 0.054	0.006 0.043	-0.035 0.060
-0.093[b] 0.045	-0.03 0.049	-0.218[b] 0.074	-0.16[b] 0.067	-0.018 0.044	-0.07 0.061
0.084[c] 0.045	0.034 0.049	-0.142[b] 0.061	-0.16[b] 0.055	-0.0072 0.039	0.023 - 0.053
0.097[c] 0.049	0.023 0.054	0.208[b] 0.072	0.134[b] 0.005	0.0034 0.037	0.066 0.051
$7.6x10^{-7}$ $5.7x10^{-7}$	$-2.9x10^{-7}$ $6.2x0^{-7}$	$-1.2X10^{-6}$[b] $5.5X10^{-7}$	$-9.8 X 10^{-7}$[c] $4.9X10^{-7}$	$6.7x10^{-7}$ $3.4x10^{-7}$	$6.9X10^{-7}$ $5.4X10^{-7}$
0.168[a] 0.015	0.185[a] 0.017	0.156[a] 0.018	0.14[a] 0.016	0.108 0.0116	0.149[a] 0.016
20.86	15.45	15.09	19.07	34.10	

(i) a ,b and c represents significant at 1%, 5%, and 10% respectively

(ii) SE,HSH, EDU, EXP, IRT, WUA, EXT, FRT , NFI , LL are respectively Standard error ,household size, Educational level, Experience, No of times irrigation was carried out, membership of Water User Association, Extension services, Fertilizer use, Income from non-farm activities and Log-likelihood

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