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EFFICIENCY OF IRRIGATED AND RAIN-FED RICE *(ORYZA SATIVA)* PRODUCERS IN FADAMA AGRICULTURE, NIGERIA

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SUMMARY

Given the importance of irrigation for rice production, this study compared the technical efficiency of irrigated and rain-fed rice *(Oryza sativa)* farms in the Upper Niger River Basin and Rural Development Authority (UNRBDA), Nigeria. Primary data were collected from 300 irrigators and 325 rain-fed rice producers. Applying the stochastic frontier Cobb–Douglas production function, net income analysis and Likert scale rating techniques, the study found that irrigated scheme increased marginal factor productivity and profitability. The study revealed the existence of large technical inefficiency in rain-fed farms when compared with irrigated farms. This suggests that there is room for output gains through technical efficiency improvement in the rain-fed system. The mean value of the marginal physical product of inputs ($VMPP_X$) in the irrigated farms (₦2.32) was more than that of rain-fed farm (₦1.67). Thus, if the average producers in the rain-fed are to achieve the technical efficiency level of the average producer in the irrigated farms, they can realize 38% output gains. Similarly, the mean net farm income (NFI) of ₦62,280.00 per ha in the irrigated farm was more than double of that of rain-fed farms ₦22,391.00. The partial regression coefficients for the individual production factors (β_1) and (β_3) for labour input (X_1) and other variable inputs (X_3), respectively, were positive and significant at 1% level, suggesting that the partial elasticity of crop output with respect to labour and other costs was higher in the irrigated farms than in the rain-fed farms. The Likert scale rating techniques showed that the poor knowledge of irrigation techniques, insufficient water for irrigation during the dry season, high cost of labour and lack of access to credit were the critical constraints preventing the rain-fed rice producer from joining the irrigation scheme. In view of this, rice irrigators should be encouraged to train more rain-fed farmers on some rudiments of irrigation techniques. They should also be linked to the sources of finance. Water Users Association (WUA) should be established in communities within the scheme areas for effective communication between farmers and the officials of the UNRBDA. Decision on the allocation of resources to Fadama sites including water should be given to WUA to strengthen the membership of the organization, while the government officials serve as supervisory and advisory body.

INTRODUCTION

Agricultural intensification by irrigation is increasingly regarded as the key to solving food supply problems in sub-Saharan Africa. However, agricultural production is mainly rain-fed and farming systems depend largely on the broad ecological zones resulting from disparity in rainfall in Nigeria. The rapid population growth coupled

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with the continuing decline in per capita agricultural productivity in sub-Saharan Africa has led to a renewed call for more irrigation development in the sub-region (Adekunle *et al.*, 2015; Carpio *et al.*, 2011; Kadigi *et al.*, 2012; Urama and Hodge, 2004).

Irrigation in agriculture is a major human use of land and water resources. About 70% of the water drawn from aquifers, streams and lakes is used in agricultural production (FAO, 2011). By 1900, there were about 40 million hectares of irrigated fields, but by 2006, this had increased to more than 301 million hectares, with much of the increase occurring in recent decades (FAO, 2011). The primary reason for the phenomenal growth in irrigated agriculture has been its perceived impact on crop productivity. Constituting only about 17% of global cropland, irrigated agriculture produced approximately 40% of the world's food in 1997 (Urama and Hodge, 2004).

Most of the irrigation is large scale within major river basins, primarily for paddy rice production. The region with the least irrigation is sub-Saharan Africa, where only 3% of the cultivated areas are irrigated (FAO, 2011). Rice production systems in Nigeria are mainly upland rain-fed, lowland rain-fed, supplementary irrigation and irrigated agriculture (Adekunle *et al.*, 2015; Daramola, 2005). Average yield of upland and lowland rain-fed rice in Nigeria is 1.8 Mg ha^{-1} while that of irrigation is 3.0 Mg ha^{-1}. This is very low when compared to other West African countries like Senegal and Cote d'Ivoire, where the average yield of upland and lowland rain-fed rice is 3.0 Mg ha^{-1} and 7.0 Mg ha^{-1} from irrigation systems, respectively (WARDA, 2003). Studies on yield potential and gap for various crops in sub-Saharan Africa showed that crop productivity could be increased several folds by improved management (Tadele, 2017). Crop intensification refers to improved productivity or output using proper agricultural input in optimum amount and time.

Traditionally, many farm families in Nigeria cultivate small areas of Fadama (low-lying swampy areas consisting of alluvial deposits and containing extensive exploitable aquifers) during dry season for income generation. These informal irrigators bought small pumps that could be used only along the bank of rivers. Thus, the area that could be irrigated was limited. Many farmers were also engaged in rain-fed farms that are adjacent to irrigated farms. Past attempts to develop irrigation have generally been unsuccessful in Nigeria and in most parts of sub-Saharan Africa. The first National Fadama Development Project implemented on February 23, 1993 was an attempt to enable farmers to participate in the formal government irrigation scheme. This project included construction of a total of 162 large dams with a total storage capacity sufficient to irrigate 725,000 hectares and distribution of more than 80,000 pumps that can irrigate 80,000 hectares in north-central Nigeria to develop irrigation (Adekunle *et al.*, 2015). However, during that period, most farmers did not benefit from formal irrigation scheme and the area under informal irrigation was greater than those under formal irrigation in north-central Nigeria.

The first National Fadama Development Project was not sustainable due to limited access to foreign exchange for importation of irrigation pumps, frequent break down of water pumps and discrimination by government officials. In order to address these issues, Fadama II and III were launched in 2004 and 2009, respectively, aiming to rehabilitate and further expand the project by increasing the number of dams and irrigation equipment including tube well and irrigation pumps in north-central Nigeria. Fadama II and III projects rehabilitated Upper Niger River Basin and Rural Development Authorities, which distributed more irrigation equipment to beneficiary communities in the three agricultural zones of the river basin. The government officials heading the scheme were mandated to increase rural and urban water supply, construct dams, weirs and control flood and erosion. A key objective of the Fadama II and III projects was to raise agricultural production and productivity by enhancing the sustainability and efficiency of the existing irrigation system, and reduce poverty.

Specifically, government and policy makers in sub-Saharan Africa have continued to support transfer of prime agriculture land from less-intensive rain-fed traditional cropping systems to intensive irrigation systems. Such decisions have been driven by two popular assumptions: (i) irrigation increases total crop output per hectare via double cropping (i.e. more food from the same piece of land per annum). In other words, irrigation is perceived to have a spatial advantage over the rain-fed cropping systems by enabling the growth of crops on the same piece of land twice each year; and (ii) irrigation improves marginal productivity of factor inputs (i.e. more food per unit input). In other terms, irrigation would have temporal advantage over rain-fed cropping system by increasing the returns per unit of input used per cropping season. In this way, irrigation would not only double crop yield per land area cropped per annum, but also reduce the amount of farm inputs required.

These perceived spatial, temporal advantages of irrigation over the traditional rain-fed cropping system are considered as the *sine qua non* for increasing crop yields and sustaining arable agriculture in Nigeria (Adekunle *et al.*, 2015; Carpio *et al.*, 2011; Ditto, 1991; Kadigi *et al.*, 2012; Urama and Hodge, 2004). Although much evidence demonstrates a relationship between government irrigation interventions and improvements in agricultural performance with respect to other River Basin of Nigeria, there is no such evidence in Upper Niger River Basin and Rural Development Authority in north-central Nigeria.

In this paper, we compared the productivity of rice production in the irrigated and rain-fed farms in north-central Nigeria, following the set of criteria outlined by Carpio *et al.* (2011) Urama and Hodge (2004). To account for the temporal and spatial issues discussed above, we compared technical efficiency of rice production in the irrigated and rain-fed cropping systems in Upper Niger River basin development of north-central Nigeria.

The contribution of this comparative analysis is four-folds. First, we compare the marginal productivities of factors in terms of rain-fed and irrigated farms per unit land per year using production function analysis. Second, we estimate the factors that contribute to variation in technical efficiency among irrigated and rain-fed farms. Third, we estimate the Likert scale rating of the factors preventing the rain-fed rice producers from joining the irrigation scheme and then we estimate the gross margin and profitability of the two systems to see the effect of irrigation on rice producer's income, draw implications of the findings and make policy recommendations.

MATERIALS AND METHODS

Description of the case study area

The Upper Niger River Basin and Rural Development Authority (UNRBDA) is the focus of the study. It is a parastatal of the Federal Ministry of Water Resources of Nigeria, with administrative headquarters in Minna Niger state. The basin covers an area of 158,000 km^2, which is located between 7^0N and 12^0N and 3^0E and 9^0E with tropical wet and dry season. The basin is drained by Niger River transboundary river, which flows from Mali as the upstream into Nigeria as the downstream country (Andersen *et al.*, 2005). Apart from the two major transboundary rivers flowing into the River Basin, the most important national streams drained to the Niger River include River Kaduna, River Gurara and River Kontangora (Jeleel, 2017).

The UNRBDA was selected for the case study primarily because it covers both irrigated and rain-fed farms within the river basin. Hence, the soil geology, hydrology and climate were the same. In addition, the land tenure and farm management systems in the irrigated and rain-fed farms were similar with the exception of the irrigation treatment. It was therefore possible to identify treatment and control farms that share similar soil management and micro-ecology.

Land tenure and cropping systems in project area

The land tenure and crop management patterns in the irrigated and rain-fed farms within the project area were similar with the exception of irrigators who were participating in formal government schemes. Most farmers own the farms plots used for irrigated and rain-fed rice production either by inheritance or purchase. The UNRBDA provides the irrigators with dams, tube well, pumps and other irrigation equipment to enable them take advantage of the perennial nature of river/stream flows for dry season farming. Few commercial farmers who are beneficiaries of Fadama III pay subscription fee per year per hectare to land owners to engage in irrigated or rain-fed rice production. The only difference in costs of natural resource inputs between the irrigated and rain-fed farms is the differential in the costs of irrigation equipment that is factored into the costs per hectare per year to irrigator's costs. In addition to irrigation equipment, UNRBDA also provides support to enhance farmers' access to improved farm machinery, fertilizer, pesticides, improved seeds, etc. meant that farmers applied these resources across the two systems (i.e. both irrigated and rain-fed farms). The costs of renting 1 hectare per year for the two systems is the same. Most farmers participating in the Fadama III have continuously produced the same variety of rice in irrigated and adjacent rain-fed farms in the river basin since 2008 even before Fadama III was implemented. This provides the opportunity to compare the productivity of rice production in the irrigated and rain-fed farms.

In summary, the shared conditions in land tenure and management patterns, micro-ecology conditions, soil types, continuous use of land for growing rice under irrigation and rain-fed farming conditions and the fungibility in the use of variable inputs between the two systems enable us to select the treatment and control that had the irrigation as the only differential.

Data sources

Cross sectional data were generated from a farm survey conducted in the UNRBDA for irrigated and rain-fed rice in 2014/15 crop year. The survey questionnaire was duly pre-tested on a randomly selected sample of 22 respondents (11 irrigation farm owners and 11 rain-fed farm owners) in June 2013. This was subsequently followed by a pilot survey of 120 farmers (60 from each group), exploring the potentials and limitations of the study (Mallam, 2013). The result of the pre-test and pilot study was used in validating the survey questionnaire coverage, timing and administration techniques adopted.

Primary data were collected by personal interviews, on-the-spot field observations and field measurement using the crop cutting techniques (CCT). Based on empirical evidence provided by Urama and Hodge (2004) and previously recommendations by FAO (1982), a 5 m^2 subplot was chosen due to the observed homogeneity in cropping density across the farm sampled. The harvested crop was then weighed (in kg) and scaled up to standard measurements (Mg ha^{-1}).

The population of the study comprised all rice farmers in the three agricultural zones, Bida, Kuta and Kontagora in the selected project areas, stratified into two groups in order to establish the counterfactual: (i) rice farmers who participated in the irrigation project and are among the Fadama III beneficiary rice producing community; and (ii) adjacent rice farmers who participated in the rain-fed project and are also among the Fadama III beneficiary rice producing communities.

Sample selection was done in two stages. First, a census survey of the selected project areas was carried out in 2013 to identify and list the two groups of farmers specified above. These lists comprising 6000 farmers in category (i) and 6500 in category (ii) served as the sampling frame. Second, equal ratios of farmers in each group (5%) were selected using a simple random sampling (SRS) technique. The numbers of farms and farmers sampled in each project area are therefore specified through the use of equal ratio of 5% for each category of farmers identified. This was necessary to make the data self-weighted in order to enhance comparison (Urama and Hodge, 2004). This gave a total of 300 irrigated farms and 325 rain-fed farms owned by respondents, respectively. The sampling percentages of 5% (of each group) were chosen because of the intensity of survey and resource constraints. The pilot survey indicated that respondents were relatively homogenous and intensive survey of randomly selected sample can produce unbiased results (Mallam, 2013).

Econometric estimation procedure

We compared the marginal productivity of factors between the irrigated crops (treatment) and rain-fed (control) using the Cobb–Douglas productions function. The goal was to test for differences in returns to factors while controlling for the potential effects of general changes such as in climate or ecology.

The stochastic form of the Cobb-Douglas production function employed is as specified below:

$$Y = AX_1^{\beta 1} X_2^{\beta 2} \; X_3^{\beta 3} \; e^{ui} \tag{1}$$

where Y is the rice output ($10^{\wedge 3}$ ha^{-1} per year), A is the scale factor (level of technology), X_1 is the amount of farm labour (10^3 ₦ ha^{-1} per year) measured as the value of the number of men days employed ha^{-1} per year, X_2 is the value of fixed costs ha^{-1} per year, X_3 is the variable capital costs (machinery, hiring costs, fertilizers, herbicides, insecticides, etc.) used (10^3 ₦ ha^{-1} per year), u is the stochastic error term, which takes account of unexplained factors affecting rice production in both systems, e is the base of natural logarithm and the exponents, β_1, β_2 and β_3 represent the relative proportions of rice output contributed by the various inputs X_1 through X_3 defined above and indicate the elasticity of output with respect to changes in the input variables X_1 through X_3.

The Cobb–Douglas production function provided the basis for estimating a multiple-log linear model, in which the parameter estimates of the explanatory were their partial production elasticity coefficients, holding other variables constant (Gujeranti, 1995). Thus, it enabled us to compare the impact of irrigation on partial productivities of factors with those of rain-fed farms in the study area. The differential intercept and the differential slope coefficients of a pooled production function were estimated. By convention, the coefficient of the dummy variable 'β_4' below tells by how much the value of the intercept term of the category that receives the value 1 differs from the intercept coefficient of the base category, while the differential slope coefficients (β_0 to β_n) show the partial elasticities of output with respect factors (X_1 to X_n) (Gujeranti, 1995).

The explicit functional form of the base model estimated is specified below:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X2 + \beta_3 \ln X_3 + \beta_4 D + \beta_5 \ln X_1 D + \beta_6 \ln X_2 D + \beta_7 \ln X_3 D + u \tag{2}$$

The differential intercept coefficient (β_4) shows the percentage change in farm output in the study area due to irrigation, while the differential slope coefficients (β_5, β_6 and β_7) show by how much the partial elasticities of output with respect to labour costs X_1, fixed costs X_2 and other costs X_3, in the irrigated farms differ from those of rain-fed farm, respectively. This means that the partial differentials of output variable Y with respect to the labour variable X_1 is $(\delta Y/\delta X)(\delta X_1/Y)$ is β_1, which by definition is the elasticity of Y with respect to X_1; similarly, the partial differentials of output variable Y with respect to the fixed cost X_2 is $(\delta Y/\delta X)(\delta X_2/\mathrm{Y})$ is β_2, which by definition is the elasticity of Y with respect to X_2; the partial differential of output variable Y with respect to other costs X_3 is $(\delta Y/\delta X)(\delta X_3/Y)$ is β_3, which by definition is the elasticity of Y with respect to X_3.

From the estimated model, the significance of the effects of irrigation on crop productivity as well as its impact on the partial productivities of factors were tested in terms of standard *t*-tests, while the general significance of the model was tested in terms of *F*-tests, all at 1%, 5% and 10% levels. This approach also has a number of advantages. First, the individual production functions for irrigated and the rain-fed farms can be deduced from the model. By assuming that $E(u) = 0$, the production functions for irrigated and rain-fed farms were given by Equations (3) and (4), respectively, and the responses of the output with respect to specific production factors were easily examined. Second, it enabled us to test the main hypothesis specified for the study: the statistical significance difference in partial productivity of factors; and on the overall production functions. The chow test would, for instance, test for statistical difference in the irrigated and the rain-fed productions, if estimated separately, but would not indicate the source (s) of the difference. The advantage of this approach therefore lies in the ability not only to test for statistical difference in crop productivity between the irrigated and rain-fed farm studied, but also test for the source (s) of the difference. The knowledge of the source(s) of difference in productivity was central to the present analysis. The difference in (partial) productivities of inputs between two systems computed from the production functions is regarded as the differential effect of the irrigation project on factor productivity in the study area. Furthermore, since the multiplicative form of the dummy variable technically increased the degree of freedom of the production function (relative to individual models for each system), it was also expected to improve the precision of the parameter estimates (Gujeranti, 1995):

$$E\,(Yi \backslash Di = 1,\ X_1) = (\beta_0 + \beta_4) + (\beta_1 + \beta_5)\ln X_1 + (\beta_2 + \beta_6) \times \ln X_2 + (\beta_3 + \beta_7)\ln X_3 \tag{3}$$

$$E\,(Y_i \backslash D_i = 0,\ X_1) = \beta_0 + \beta_1 \ln X_1 + \beta_2\ \mathrm{In}\ X_2 + \beta_3 \ln X3 \tag{4}$$

Despite the restricted econometric model assumed in the Cobb–Douglas production function, this approach utilizes the basic framework that has been applied in similar studies (Urama and Hodge, 2004) and provides a basis for comparability of empirical results. Due to its simplicity and convenience, the Cobb–Douglas production function has been widely used in agricultural economic research (Allen *et al*., 2014; Tiedemann and Latacz-Lohmann, 2013).

Likert scale rating technique

A four-point Likert scale was adopted and graded as very serious = 4, serious = 3, not very serious = 2 and not serious = 1. Based on this grading, the problems preventing the rain-fed producers from joining the irrigated scheme were ranked using weighted mean. The mean score of respondents based on the point scale is 4+3+2+1 = 10/4 = 2.5. Using the interval scale of 0.05, the upper limit cut off point was 2.5+0.05 = 2.55 and the lower limit was 2.5–0.05 =2.45. Then, any mean score (MS) below 2.45 was ranked as 'not serious, and not very serious', while between 2.45 and 2.55 were considered as 'serious', while any MS greater than or equal to 2.55 was considered as 'very serious'.

Table 1. Sample population statistics.

Variables	Irrigated farm plot		Rain-fed farm plot	
	Mean	Sd	Mean	Sd
Years of formal schooling	7.31	0.51	4.91	0.29
Age in years	45.23	0.67	48.56	0.71
Gender (Male = 1, female = 2)	1.16	0.04	1.17	0.04
Year of farm experience	10.94	0.23	11.46	0.36
Farm size in ha	1.89	4.38	2.45	3.40
Output (in Megagram (Mg))	2.16	0.09	1.17	0.58
Output in naira	118,800.00	4950.00	64,350.00	31,900.00
Labour	31,024.62	2792.21	22,855.00	3631.00
OVC	20,270.00	6450.00	15,540.00	4476.83
TVC	51,294.00	9242.00	38,395.00	11,061.00
GM	67,506.00	11,956.00	25,955.00	7477.00
TFC	5226.00	856.00	3564.00	1034.00
TC	56,520.00	10,098.00	41,959.00	12,095.00
NFI	62,280.00	11,100.00	22,391.00	6443.00
N	300		325	

Source: Survey data 2014. Software used =STATA 13.0.
Note: Output = market value of rice output/ha; Labour = labour cost/ha (including labour for the use of irrigation pump in irrigated farms only); OVC =other variable costs/ha (seed, seed chemical, inorganic fertilizer, herbicides, pesticides, packaging material); TVC = total variable costs of production computed as labour + OVC; GM = gross margin per hectare; TFC = total fixed costs (costs of depreciation on cutlasses, hoes, axes, sprayers, sickles, irrigation pump and ₦1000 per ha per year on land rent); TC = total costs; NFI = net income; Sd = standard deviation, and N = sample size.

RESULTS

Summary statistics of the survey data

In this sub-section, we described the general descriptive statistics of the survey data including the gross margin budgets and profitability for irrigated and the rain-fed farms based on the cross sectional data for 2014/15 cropping seasons following the comparative analysis framework specified in Supplementary Table S1 (available online at http://dx.doi.org/10.1017/S0014479718000212). The aim is to provide background information relevant to the production function analysis. The demographic characteristics of the farmers are presented in Table 1. Both groups of farmers were mostly middle age (about 40 years on average) with 80.3% between 35 and 65 years, had only primary education (less than 8 years of formal education) with 86% below secondary education and held between 1 and 6 hectares of rice field in UNRBDA. On the average, they were all experienced rice farmers (i.e. have spent between 10 and 25 years as a rice farmer in the project area). About 96% of the interviewed farmers were married. The proportions of farmers by gender in the irrigated and rain-fed farms were 20% and 15% females in the rain-fed and irrigated farm, respectively. Farming was the primary source of livelihood among the respondents.

The main difference observed between the irrigated and rain-fed farms relates to the cost of farm inputs and value of farm outputs per unit land per year. As shown in

Table 2. Estimated production function comparing the two systems.

Variables in natural logarithms	Symbol	Model 1.1 Estimated coefficient	Model 1.2 Estimated coefficient (irrigation)	Model 1.3 Estimated coefficient (rain-fed)
Constant	β_0	8.95 (3.26)**	4.55 (3.57)**	8.95 (2.64)**
Labour costs per year	X_1	0.50 (4.94)***	0.58 (5.22)***	5.0 (4.22)***
Fixed costs per year	X_2	0.92 (1.85)*	−0.01 (1.67)*	0.92 (1.61)*
Other variable inputs per year	X_3	0.42 (4.64)***	0.40 (5.25)***	0.42 (4.21)***
Dummy variable (1= irrigation; 0 = rain fed)	D	06.91 (1.49)*		
Labour dummy	X_1D	0.16 (2.55)**		
Fixed cost dummy	X_2D	−0.30 (0.82)		
Other costs dummy	X_3D	1.40 (2.0)*		
Number of observations		625	300	325
F-statistic		252.66	34.87	69.57
R^2		0.82	0.50	0.70
Adjusted R^2		0.81	0.48	0.69

Source: Survey data 2014. The absolute t-statistics associated with the underlying coefficients reported in brackets. *coefficient significant at 10% level; **coefficient significant at 5%; ***coefficient significant at 1%.

Table 1, the fact that some farmers could double production per year in irrigated farm as well as labour costs for using irrigation pumps increased variable costs. However, this opportunity to double crop output also double the costs of labour and other variable costs. While the mean costs of input per hectare per year (total variable costs) in the rain-fed farms was ₦38,395 that of irrigated farms was ₦51,794.00. Hence, the mean annual gross output margin of the irrigated farms was ₦67,006.00 and that of rain-fed was ₦25,955.00. Thus, the gross margins of the irrigated rice per hectare were more than double the amount of gross margin ha^{-1} in rain-fed rice.

The mean value of the marginal physical product of inputs ($VMPP_X$) in the irrigated farms (₦2.32) was higher than that in the rain-fed farm (₦1.67). This suggests that irrigated farms performed better than the rain-fed farms. The mean NFI of ₦62,280.00 ha^{-1} in the irrigated farm was more than double of that of the rain-fed farms ₦22,391.00.

The production function

A pooled regression function of the type specified in Equation 4 was estimated for the irrigated and rain-fed farms studied and relevant null hypotheses were tested in terms of t-test and F-tests, respectively. The estimated model is summarized in Table 2. Overall, the estimated production is statistically significant at 5% ($F_{7,598} = 252.66$; $p \leq 0.0001$). The estimated R^2 of 0.8162 indicates that about 82% of the variation in output is statistically explained by the explanatory factors in the model. There was no evidence of multi-collinearity or heteroschedasticity in the model.

The partial regression coefficients for the individual production factors (β_1) and (β_3) for labour input (X_1) and other variable inputs (X_3), respectively, were positive

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Table 3. Mean distribution of factors preventing rain-fed farmers from irrigating their rice farms.

Rain-fed producers	
Constraints	Mean
Poor knowledge on irrigation techniques	3.55***
Insufficient water for irrigation during the dry season	3.88***
High cost of labour	3.22***
Access to credit	2.98***
High cost of farm operation and maintenance	3.45***
Poor response to farmers' need by URBRDA officials	3.79***
Irregular pumping of water	3.66***
Phasing off sprinkler system	3.11***
Inability to channel water to the plot	2.67***
Land acquisition	1.17*
Lack of high yielding seed	1.34*
Inability to sell farm produce	1.54*
Inadequate storage facilities	1.31*

Sources: Survey data 2014. *not serious constraint; **serious constraint; ***very serious constraint.

and significant at 1% level, while that of fixed costs (X_2) was significant and positive at 10%, suggesting that production increases with higher endowments of these significant factors. A Cobb–Douglas production function estimated for the irrigated and rain-fed farms in the river basin only, found similar results with $R^2 = 0.92$ (Urama and Hodge, 2004).

The differential intercept coefficient was significant at 5%, suggesting that the intercepts for the production functions for the irrigated and rain-fed farms were significantly different from zero. The differential slope coefficient for land rent (costs of land rent ha^{-1} per year) was not significant, suggesting that the partial elasticity of crop output with respect to land was not significantly different in the irrigated and in the rain-fed farms. The differential slope coefficient for other inputs was significant at 1% and positive, indicating that the partial elasticity of crop output with respect to other input (costs of depreciation on cutlasses, hoes, axes, sprayers, sickles, irrigation pump, seed, seed chemical, inorganic fertilizer, herbicides, pesticides, packaging material) was significantly higher in the irrigated farms compared to the rain-fed farms. A unit increase in other inputs in irrigated farms increased crop productivity by about 15% more than the same unit increase in variable inputs in the rain-fed farms. The increase in the productivity of labour due to irrigation was also significant and positive at 5%. Thus, a unit increase in labour input in the irrigated farm increased crop productivity by about 38% more than the same increase in labour input in rain-fed farms.

The Likert scale rating technique

Our study revealed various factors affecting farmers' participation in irrigated scheme at the Upper Niger River Basin and Rural Development Authority using the Likert scale rating technique (Table 3). Limited knowledge on the irrigation techniques especially on water channel construction was a very serious problem, the MS was 3.55. Most rain-fed rice producers claimed that they are not able to construct water channel and irrigation farming is highly dependent on water supply. Insufficient water for irrigation during the dry season was also ranked by the rain-fed rice producers as a very serious problem preventing them from irrigating their farm (MS was 3.88). Higher cost of labour (MS = 3.22), access to credit (MS = 2.98) and higher cost of farm operation and maintenance (MS = 3.45) were regarded as some of the very serious economic problems preventing the rain-fed farmers from joining the irrigation techniques. Our results also indicate that poor response to farmers need by officials (MS = 3.79), irregular pumping of water (MS = 3.66), phasing off sprinkler system (MS = 3.11) and inability to channel water to the plot (MS = 2.67) were all ranked as very serious problem. Problems that were reported as not affecting farmers' participation in irrigation scheme were land acquisition, lack of high yielding seed, inability to sell farm produce and inadequate storage space.

DISCUSSION

The estimated model suggests that the rice irrigators are more efficient than the rain-fed rice producers supporting of the commonly held idea that *cetris paribus,* agricultural intensification by irrigation, is regarded as the key to solving food supply problems in sub-Saharan Africa (Ditto, 1991).

Several empirical studies have reported a positive and significant association between coefficients for the individual production factors such as labour input, variable inputs and total fix costs with the technical efficiency, suggesting that production increases with higher endowments of these factors. The mean value of the marginal physical product of inputs ($VMPP_X$) in the irrigated farms (₦2.32) was more than that of the rain-fed farms (₦1.67) and reveals that irrigated farms performed better than the rain-fed farms in terms of marginal return to farmers. Thus, if the average producers in the rain-fed farms are to achieve the technical efficiency level of the average producer in the irrigated farms, they can realize 38% output gains. The overall significance of the production function is consistent with findings elsewhere (Urama and Hodge, 2004; Tiedemann and Latacz-Lohmann, 2013). Similarly, the mean net farm income (NFI) of ₦62,280.00 per ha in the irrigated farms was more than double of that of the rain-fed farms ₦22,391.00. This finding suggests that the irrigated farms performed better than rain-fed farm in terms of gross margin, net farm income and marginal returns to farmers.

The Likert scale rating techniques showed that poor knowledge of irrigation techniques is a serious problem, implying that farmers in this area need training on the irrigation techniques, especially on water channel construction. In fact, irrigation farming is highly dependent on water supply and inability to get it resulted to loss of crops and income for the farmers. The analysis also revealed that insufficient water for irrigation during the dry season prevents the farmers from participating in irrigation. This is because water availability in terms of equitability, adequacy and timeliness would be the motivating factor for producers to participate in irrigation farming. Similar finding was reported by Adekunle *et al.* (2015) and Oriola (2009), showing that unreliable supply and distribution of irrigation water turned many farmers dissatisfied and unwilling to participate. Economic factors including higher cost of labour in the irrigated farm than the rain-fed farm, lack of access to credit and inability to purchase pumping machine needed to irrigate farms were the critical constraints preventing the rain-fed rice producer to participate in irrigation scheme. Other problems include managerial and administrative problems by the officials of the UNRBDA. Our data indicated that poor response to farmers' need by official is a serious problem preventing them from irrigating their rice farm. Irregular pumping of water, phasing sprinkler system and inability to channel water to the plot were reported as factors that affect the yield and prevent farmers from participating in the scheme.

As irrigated rice improves the income of farmers for better livelihood, factors preventing them from participating in the irrigation scheme should be addressed properly by the policy makers. Any policy reform that focuses on timeliness, adequacy and equitability of water will surly lead to increased participation and more income to producers of rice. As suggestion, officials of the UNRBDA to encourage farmers to participate in irrigation farming by asking other trained irrigator rice farmers to train more rain-fed farmers on some rudiments of irrigation techniques. They should also be linked to the sources of finance where loans can be easily accessed for production purposes. Water users association should be established in communities within the scheme areas for effective communication between farmers and the officials of the UNRBDA. Finally, decision on the allocation of resources to Fadama sites including water should be given to water users association while the officials would serve as supervisory and advisory body.

CONCLUSION

This paper contributes to the literature on agricultural production efficiency and in the context of irrigated and rain-fed rice cropping systems in UNRBDA, Nigeria. Herein, four research questions were asked: Does irrigation significantly increase marginal productivity of factors in the river basin? Does irrigation significantly influence the technical efficiency of farmers? Does irrigation significantly increase the net profit? What are the problems preventing rain-fed farmers from irrigating their farms?

Our findings confirm that all key production factors – labour, fixed costs and other variable costs – have a positive sign and significantly influenced technical efficiency. The marginal product of other costs was significantly higher in irrigated farms than in the rain-fed counterpart. Also, marginal returns to production were lower in the rain-fed farms than in their irrigated farms. Thus, labour (including labour for the use of irrigation pump in irrigated farms only) and other costs (costs of depreciation on cutlasses, hoes, axes, sprayers, sickles, irrigation pump, seed, seed chemical, inorganic fertilizer, herbicides, pesticides, packaging material) and land rent were all being more judiciously used by the irrigated rice farm than by the rain-fed farmer. The Likert scale rating techniques showed that the poor knowledge of irrigation techniques, insufficient water for irrigation during the dry season, high cost of labour and lack of access to credit were the critical constraints preventing the rain-fed rice producer joining the irrigation scheme.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/S0014479718000212

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