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Needed Resource Adjustment for Boosting Irrigation Rice Production: A Case of Ogun-Osun River Basin Authourity in Nigeria

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***Abstract*: River Basin Development Authorities is developed to encourage agriculture through irrigation in Nigeria stochastic frontier approach was used to analyzed efficiency of smallholder rice farmers. Inefficiency model was used to analyse factors underlying efficiencies differentials among the sampled households. Results revealed average technical, allocative and economic efficiency levels of 65.5, 59.4 and 53.3, respectively. Hence farmers in the irrigation schemes have a rice yield potential of 35.4% to be exploited and can raise their profitability or rice production by 47.2% by adjusting input use. Soil fertility status, access to credit, household size and farmer experience were the factors that influenced the efficiency levels. It is recommended that for improved efficiency levels there is need for better policies and strategies for good soil fertility management options and those that will reduce farmer's non-access to credit and ensuring that it is accessed at the right time.**

***Keywords*: Resource adjustment, rice production, Ogun-Osun River Basin Authority, Nigeria.**

I. INTRODUCTION

Major rivers capable of supplying irrigation water to the farmers is the Ogun - Osun River along with its smaller tributaries. This was the reason for the establishment of Ogun - Osun river Basin Development Authority alongside other River basin Development Authorities in the country in 1970 by the Federal Government. The main function of the River Basin Development Authorities is to develop infrastructures in areas close to the big rivers and encourage agriculture through irrigation. The study area has a wide distribution of rivers, streams and lowlands that are often explored by local farmers especially for dry season farming. Farmers usually plant Okra, *Amaranthus* spp and *Chocorus olitorius* through irrigation in the areas during dry season. Only few farmers plant rice and maize sparsely on irrigated farms but this study focus on measurement of efficiency of smallholders irrigated scheme farmers that get water through Ogun-Osun river basin authority. Several agro-allied industries are also located in this area. The below diagrams show ogun-osun river basin authority in Nigeria.

Source: Google Map

Past studies revealed that rice (*Oryza sativa*) is the second main cereal food crop after maize (*Zea mays* L.). For some time, yield levels of rice have been stagnant; for instance in most flood plains yield levels range from 1.0-1.5 t ha^{-1}. However, under good management the potential yield levels range from 5 - 6 t ha^{-1} (Government of Nigeria, 2012/13). The wide gap in yields indicates possibilities of improving rice productivity. Recently, Nigeria government is failing to meet its cereal food requirements. This has been attributed to the failure of food production to keep pace with the growing population; droughts and inability of farmers to efficiently use available water for production, declining soil fertility as well as small land holding size of smallholder farmers. Additionally, there is a strong farmer perception that maize is the only food crop and, hence, failure to diversify (FAO, 2008).

In addition, for the past 15 years irrigation has had low priority in agricultural production in Nigeria (FAO, 2006). Some of the constraints have been the reliance on rain fed agriculture, reluctance of donors to fund irrigation development, price setting for crops not viable for irrigation, the lack of irrigation technology training facilities within the country and finally the lack of farmer ownership of land on government irrigation schemes (FAO, 2006).

According to food and agriculture organization in 2006, irrigated agriculture is being promoted not only as a way of fostering rural development, but also as a means of reducing rural poverty, malnutrition, and diseases, as well as stemming the growing social economic inequalities between rural and urban areas. Recent reports, however, indicate that agronomic efficiency in smallholder crop production remains very low (Tchale, 2009; Edriss, 2003; Government of Nigeria, 2006. Further analysis is required to understand factors affecting and interventions necessary to increase efficiency of crop production in smallholder agriculture. This study was, thus, conducted to evaluate farmer specific technical, allocative and economic efficiencies for rice producers in Ogun-Osun river basin authority and identify social economic characteristics that influence both efficiency phenomena in the Irrigation Scheme.

II. METHODOLOGY

The study used both primary and secondary sources of data. Primary data were sourced through interviews with rice producers in the irrigation scheme, using a structured questionnaire. The questionnaires captured data on farmer's rice production levels, costs incurred in rice production and production related socio economic factors. The household interviews captured data on rice yields, availability of labour, amount of inputs and type of inputs used in rice production; extension contacts, production costs and access to credit. Furthermore, socio-demographic data were also captured. Secondary data were sourced from documents from various stakeholders like CIAT, Irrigation rural Livelihoods and Agricultural Development (IRLAD), Ministry of Agriculture, policy documents and past research.

The study employed the stochastic frontier parametric approach specified by Battese and Coelli (1995) to evaluate TE, AE and EE of rice production. One-stage stochastic production frontiers approach was used to estimate the determinants and distribution of farmer efficiency in this analysis. This involves regressing output on the input variables, as well as the socio-economic variables that determine inefficiency in rice production. In order to correct for possible heteroscedasticity, robust standard errors (presented in parenthesis in result Table 1 and 3) were estimated in both the stochastic production frontier and the stochastic cost frontier. The maximum likelihood estimates (MLE) of the parameters of both functions were obtained using the STATA Program. Furthermore, the elasticity's of mean output were estimated at the means of the input variables.

$$\ln(Y_i) = \beta_0 + \sum_{a=1}^{4} \beta_a \ln(x_{ai}) + \frac{1}{2}\sum_{a=1}^{4}\sum_{b=1}^{4} \beta_{ab} \ln(x_{ai}) \ln(x_{bi}) + v_i - e_i \quad \text{.................. (1)}$$

Where: Y_i denotes total rice output in kg and i= 1, 2, 3 … 200 observations;

$X_a, a = b = 1,2,3,4$ are four physical input variables included, namely, X_1 = total area planted to rice in hectares (ha); X_2 = total family labour and hired labour used (man-days); X_3= total quantity of seed used (kg); X_4 = total quantity of fertilizer used (kg); e_i= farm specific/social economic characteristics related to production efficiency; v_i = random variables associated with disturbances in production

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In the translog function, the elasticities of mean output with respect to each of the inputs were defined by:

$$\frac{\partial \ln E(Y)}{\partial \ln X_a} = \beta_a + \beta_{aa}\overline{\ln X_a} + \sum \beta_{ab}\overline{\ln X_{ab}} - \theta_i\left(\frac{\partial \mu_i}{\partial X_{ai}}\right), a = 1,2,3,4. \quad \text{……………….. (3)}$$

Where θ_i, represents the density and distribution functions of the standard normal random variable, the last term in equation 3 drops out for all variables and at the mean values of the inputs, elasticities were computed.

Computing Economic efficiency index

From a Cobb-Douglas stochastic cost frontier function, the trans-log cost frontier takes the following form:

$$\ln C_a = \ln \alpha_0 + \sum_{i=1}^{4} \alpha, \ln p_i + \frac{1}{2}\sum_{i=1}^{4}\sum_{j=1}^{4} \varphi_{ij} \ln p_i \ln p_j + \alpha_y \ln y + \frac{1}{2}\varphi_{yy}(\ln y)^2 + \sum_{i=1}^{4}\varphi_{iy} \ln y \ln p_i + v_i + e_i \quad \text{…………………………………………………………………………………… (8)}$$

Where C_i denotes cost of producing output of rice in Mk; p_i i=j=1, 2, 3, and 4 are four input variables considered in the analysis namely; p_1= total seasonal rent of a hectare of land (MK); p_2 = total labor cost (MK) ;p_3 = total price of fertilizer per kg (MK); p_4 = total price of seeds (MK); e_i = farm specific/social economic characteristics related to production efficiency and v_i = random variables associated with disturbances in production.

Adding up $\alpha p_1 + \alpha p_2 + \alpha p_3 + \alpha p_4 = 1$ ………………………………………………. (9)

$$\varphi p_1 p_1 + \varphi p_1 p_2 + \varphi p_1 p_3 + \varphi p_1 p_4 = 0$$
$$\varphi p_1 p_2 + \varphi p_2 p_2 + \varphi p_2 p_3 + \varphi p_2 p_4 = 0$$
$$\varphi p_1 p_3 + \varphi p_2 p_3 + \varphi p_3 p_3 + \varphi p_3 p_4 = 0$$

Homogeneity $\varphi p_1 p_4 + \varphi p_2 p_4 + \varphi p_3 p_4 + \varphi p_4 p_4 = 0$ ……………………………… (10)

Symmetry $\varphi_{ij} = \varphi_{ji}$ ………………………………………………………………….. (11)

Derivation of allocative efficiency

Estimation of AE can be achieved through use of efficiency results from TE and EE; where EE is derived from the CE function. According to Farrell (1957) and Bravo-Ureta and Pinheiro (1997); EE is the product of TE and AE. From this, therefore, it is possible to compute AE as follows:

$$\frac{CE_i}{TE_i} = \frac{\left(\dfrac{c(p_i, q_i, \beta)Exp\{u_i\}}{C_i}\right)}{\left(\dfrac{Y_i}{f(x_i, \beta)\exp(v_i)}\right)} \quad \text{…………………….…………………………………… (12)}$$

In one-step procedure, the inefficiency e_i is related to the exogenous factors of rice production by;

$$e_i = \sigma_0 + \sum_{n=1}^{m} \sigma_n Z_{ni} \quad \text{………………………………………………………………… (13)}$$

Where Z_i is a vector of farm-specific explanatory variables which are determinants of inefficiency. These include, land husbandry practices like weeding, climatic conditions like rain fall etc. In addition, it is also a vector of individual characteristics such as education level, household size and age.

III. RESULTS AND DISCUSSION

The positive sign of land, seed, labour and fertilizer implies that as such variables are increased, rice output increases. The findings further show that rice production is significantly correlated to the physical production inputs of land and fertilizer (Table 1). The log-likelihood of -198.04 indicates the overall significance of the estimated of rice production. Results in Table 1 indicate that all the variables coefficients of the physical inputs in the model have expected a priori signs. The significant positive relationship with land and fertilizer indicates that these are the crucial inputs that affect technical efficiency of rice production in the study area. These results are in agreement with Abedullah et.al 2007 who found out that area under rice production and amount of fertilizer applied significantly affect technical efficiency of rice farmers. Furthermore the results indicate that the coefficient of land and seed ratio also significantly affect technical efficiency. These results differ with what Huynh viet Khai (2011) whose results indicated that ratio of land and labour significantly affect technical efficiency of rice farmers. Although some of the production inputs were significant and had the expected signs, results of the first order translog production function coefficients are not conclusive as they do not provide much information on the responsiveness of the output to the various inputs. Based on this argument, output elasticities of each of the physical input used at their mean values were computed. The output elasticities of all the inputs are positive (Table 2). These estimates are 0.59, 0.04, 0.02 and 0.14 for land, labor, seed and fertilizer, respectively. The results demonstrate the high response of rice to land and fertilizer. Considering the first hypothesis of this study, the presence of technical inefficiency effects in the model, and all deviations from the production frontier are due to statistical noise if $\lambda = 0$ (Coelli *et.al*, 2002). Therefore, the presence of technical inefficiency effects in rice production is tested by the significance of the variance parameters.

From Table 1, the estimated value for λ is large and significantly different from zero ($\lambda = 1.5378$). Therefore, the null hypothesis of no technical inefficiency in rice production is rejected (5 percent significance level). The variance parameter σ^2 is significantly different from zero ($\sigma^2 = 0.5418$). The inefficiency effects are, therefore, random and stochastic. The ratio of plot-specific technical efficiency effects to the total output variance, expressed as γ takes on a value of 0.7028 this represents the inefficiencies that are unexplained by the production function and also the dominant sources of fluctuations in rice production among rice farmers. This implies that about 70 percent of the variation in rice output is due to differences in technical efficiency among the farmers. This is in agreement with the findings of Fakayode (2009) which indicated γ of 0.6975 implying that the systematic influences that were unexplained by the production function were the dominant causes of rice yield differences among farmers.

Table 1: Maximum-likelihood estimates of the parameters

	Parameter	Estimated coefficient	Robust Std. Error
Intercept	β_0	1.1544	0.5983
Lnland	β_1	0.5382***	0.1022
Lnlabour	β_2	0.00420	0.0510
Lnseed	β_3	0.13710	0.1004
Lnfertiliser	β_4	0.11940*	0.0679
$1/2$ Lnlansqrd	β_5	-0.4474**	0.1564
$1/2$ Lnlaborsqrd	β_6	-0.1370	0.1050
$1/2$ Lnseedsqrd	β_7	0.5474*	0.2969
$1/2$ Lnfertilisersqrd	β_8	-0.1256	0.0854
Lnland*Lnlabour	β_9	-0.0680	0.1440
Lnland*Lnseed	β_{10}	0.3276*	0.1649
Lnland*Lnfertliser	β_{11}	0.0885	0.1517

Lnlabor*Lnseed	β_{12}	-0.0373	0.1434
Lnlabor*Lnfertiliser	β_{13}	0.0548	0.0662
Lnseed*Lnfertiliser	β_{14}	0.0167	0.1203
Variance parameters			
Lamda	λ	1.5378**	0.2277
Sigma squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.5418**	0.1166
Sigma-u	σ_u	0.6171**	0.1399
Sigma-v	σ_v	0.4013**	0.0912
Gamma	$\gamma = \lambda^2/(1+\lambda^2)$	0.7028**	
		Chibar2(24) = 310.74***	Prob>=chibar2=0.000
Log-likelihood		-198.04	
Number of observations	N	245	

*** Significant at 1%; ** significant at 5%; *significant at 10%

Table 2 indicates the computed elasticities at the mean values of the inputs. A percentage increase in land allocated to rice leads to a 59 percent increase in the output. Furthermore, a percentage increase in labour used results in a 4% increase in output. Similarly, a percentage increase in fertiliser applied leads to a 14% increase in the output. Finally a percentage increase in quantity of seed used leads to a 2% increase in rice output.

Table 2: Input elasticities

Input	Elasticity
Land	0.590
Labour	0.040
Seed	0.020
Fertiliser	0.140

The level of technical efficiency was computed for each farm (Table 4). Mean technical efficiency for rice farms was 65 percent, with a minimum of 13 percent and a maximum of 93 percent; and a standard deviation of 14 percent. About 92 percent of the farmers had technical efficiency levels of less than 80 percent. This indicates that in the short run, there is large scope for efficiency gains. Rice farmer's levels of technical efficiency can be increased by up to 40 percent on average using the best practice technology. Therefore, 40 percent of smallholder rice yield is lost due to inefficiency. This implies that identifying and addressing the major factors that constrain efficiency in smallholder rice production could increase productivity considerably.

In addition, the log-likelihood estimate of -220.6924 shows the overall significance of the estimated translog stochastic cost frontier function of the rice farmers. The model has a Wald test statistic of 689.06 with a p-value of 0.0000. Presence of economic inefficiency effects in the model, and all deviations from the cost frontier are due to statistical noise if $\lambda = 0$ (Coelli *et.al*, 2005). Therefore, the presence of cost inefficiency effects in rice production is tested by the significance of the variance parameters.

Also, from Table 2, the estimated value for λ is large and significantly different from zero ($\lambda = 2.4871$). Therefore, the null hypothesis of no cost inefficiency in rice production is rejected (5 percent significance level). Results of the coefficients of the cost variables in Table 2 indicates that rice yield and labour cost significantly influence cost of producing output of rice. The The significance of gamma ($\gamma = 0.8608$) shows that the frontier is stochastic implying that 86 percent variation in rice output among the farmers due to presence of inefficiencies.

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From Table 3, the estimated mean cost efficiency is 53% and this indicates that farmers could raise the profitability of rice production by an average 47% through optimum use of inputs, especially labour. Economic efficiency of the rice farmers may also as a result of higher technical inefficiencies obtained and poor allocation of inputs. Estimated efficiency of sampled farms vary from one study to another due to various reasons such as, differences in time of data collection, differences in farm structures etc. This is much lower than the economic efficiency of 69% obtained by Bradley et al (2013), 81% obtained by Huang et al (2002) and 83% obtained by Xu and Jeffrey(1998) all studies were on rice.

Table 3: Maximum-likelihood estimates of the parameters

	Parameter	Estimated coefficient	Robust Std. Error
Intercept	α_0	14.1156	0.3204
Lnyield	α_1	0.2561***	0.7589
Lnlandcost	α_2	-0.1228	0.1160
Lnlabourcost	α_3	1.0614***	0.8334
Lnseedcost	α_4	0.1093	0.1040
Lnfertilisercost	α_5	-0.0480	0.0682
$1/2$ Lnlancostsqrd	α_6	0.1636	0.2758
$1/2$ Lnlabourcostsqrd	α_7	0.2157	0.2726
$1/2$ Lnseedcostsqrd	α_8	0.3310***	0.9944
$1/2$ Lnfertilisercostsqrd	α_9	-0.1124	0.1268
$1/2$ Lnyieldsqrd	α_{10}	0.1687***	0.0524
Lnlandcost*Lnlabourcost	α_{11}	-0.2424	0.2328
Lnlandcost*Lnseedcost	α_{12}	0.0072	0.1110
Lnlandcost*Lnfertlisercost	α_{13}	0.0715	0.1949
Lnlabourcost*Lnseedcost	α_{14}	-0.1762	0.1471
Lnlabourcost*Lnfertilisercost	α_{15}	0.2029	0.1241
Lnseedcost*Lnfertilisercost	α_{16}	0.1877	0.1195
Lnyield* Lnlandcost	α_{17}	-0.1496	0.1532
Lnyield* Lnlabourcost	α_{18}	-0.1643	0.1514
Lnyield* Lnseedcost	α_{19}	0.0214	0.0950
Lnyield* Lnfertlisercost	α_{20}	0.0015	0.0960
Variance parameters			
Lamda	λ	2.4871**	0.1704
Sigma squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.8307	0.1424
Sigma-u	σ_u	-0.3354	0.2518
Sigma-v	σ_v	-2.1576**	0.4199
Gamma	$\gamma = \lambda^2/(1+\lambda^2)$	0.8608**	
Log-likelihood=-220.6924	Chibar2(15) = 603.34***		Prob>=chibar2=0.000

*** Significant at 1%; ** significant at 5%; *significant at 10%

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Results from Table 4 indicate large variations in performance across farms. Allocative efficiency of rice farmers ranged from 13 to 91 percent. This implies that if the average farmer in the sample was to achieve the allocative efficiency level of his or her most efficient counterpart in Southern Malawi, he or she should increase the allocative efficiency by 35 percent. This is the percentage increase in allocative efficiency obtained by using the following formula: (1-59.41/91.23)) *100 where the figures are the mean and maximum levels of allocative efficiency as shown in Table 4. Allocative inefficiency was worse than technical inefficiency; hence, low level of economic efficiency was due to higher costs of inefficiency. These results are lower than 81% and 78% what Coelli et al (2002) found on Boro rice farms and Aman rice farms in Bangladesh. Further research results from Nhut (2007) and Xu and Jeffrey (1998) of 81% and 88% respectively were higher than the results of this study. The lower allocative efficiency might be due to limited experience of the rice farmers in rice farming.

Table 4: Average percentage of Smallholder rice farmers

Efficiencies	Mean efficiency (%)	Min (%)	Max (%)	Standard deviation
TE	65.49	13.31	93.23	13.59
AE	59.41	12.86	91.23	16.36
EE	53.32	12.41	89.23	19.13

TE = Technical Efficiency AE = Allocative Efficiency EE =Economic Efficiency

Figure 1 shows the distribution of efficiency estimates. It is apparent that the scope of efficiency gains was fairly large. Economic efficiency in smallholder rice farming system could be increased by up to 50 percent using the current production technology. This, therefore, implies that smallholder productivity could double if key factors that are currently constraining overall efficiency are addressed adequately.

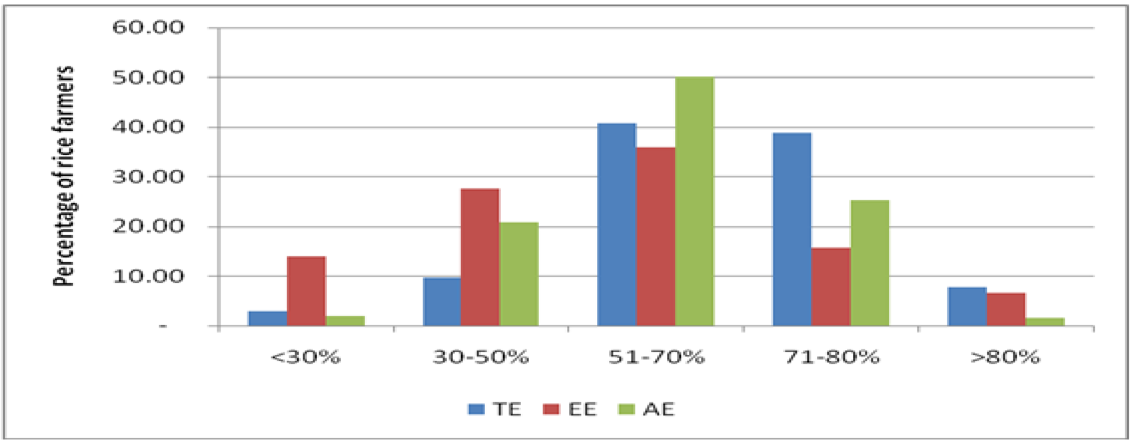

Figure 1: Average proportion efficiency in smallholder rice production in Ogun- Osun River Basin Authority

The coefficient for high soil fertility is significant and negative; suggesting that it negatively influences efficiency. The negative influence of high soil fertility levels on inefficiency indicates that those farmers who cultivated on high fertile soils are less inefficient in rice production. On the other hand farmers who cultivated on less fertile soils are more inefficient in rice production even if they use improved seeds. These therefore entail that rice farmers stand a better chance of improving their efficiency levels if they improve the fertility of their soils. More experienced farmers were in a better position of understanding and integrating agricultural instructions and apply technical skill imparted on them. Increased farming experience may result in efficient input use.

In addition, experienced farmers therefore are better positioned to produce more rice than the in experienced ones. In addition to the above, household size and access to credit have positive and significant impact on economic efficiency on rice production. Hence, they have an inefficiency increasing effect. The positive coefficient of household size on stochastic cost frontier model results indicates that the economic inefficiency of rice farms increases with increase in household size. In order to support large families most households find it difficult to optimally allocate their finances between household consumption and farm operations, hence economically inefficient rice farms. Furthermore, the significant and positive coefficient on access to credit entails the higher the access to credit, the more inefficient the farmer became.

As argued by Okike et.al (2001) receiving credit contributed to farmer's economic inefficiency. Hence if production credit is invested on the farm it is expected that it will lead to higher levels of output, however in case the credit is not accessed on time which is very typical in African settings in may lead to misuse of the funds by allocating to other things such as consumption and not the intended purpose. Hence the impact of the credit will not be felt on the farm. Although the rest of the variables turned out to be insignificant, they have a *priori* expected signs. The negative sign on the coefficient of age of farmer indicates that younger farmers were more efficient than the older farmers. This could be explained by older farmer's unwillingness to adopt modern technologies. In addition, the older the farmer gets, the more their physical strength declines. An implication of this is that although older farmers are more skillful and experienced the effects of learning by doing diminishes over time (Liu & Zhuang, 2000).

Table 5: Maximum Likelihood Estimates of the Inefficiency Model

		Stochastic production frontier		Stochastic cost frontier	
	Parameter	Estimated coefficient	Robust std errors	Estimated coefficient	Robust std errors
Age	δ_1	-0.0003	(0.0022)	-0.0023	(0.0026)
Household size	δ_2	0.0006	(0.0182)	0.0650***	(0.0195)
School years	δ_3	0.0017	(0.0075)	0.0042	(0.0072)
Access to credit	δ_4	-0.3354	(0.2748)	0.3021**	(0.1480)
Medium soil fertility	δ_5	-0.0513	(0.0.0811)	-0.1426	(0.0924)
High soil fertility level	δ_6	-0.1399*	(0.0775)	-0.0891	(0.0983)
Years of growing rice	δ_7	0.0086**	(0.0041)	0.0146***	(0.0042)
Access to extension advise	δ_8	-0.0505	(0.0818)	-0.0231	(0.1130)
Distance to input/output markets	δ_9	-0.0068	(0.0165)	0.0152	(0.0126)
Log-likelihood		-198.0406		-220.6924	
Number of observations	n	245		245	
		Chibar2(24) = 310.74*** Prob>=chibar2=0.000		Chibar2(15) = 603.34*** Prob>=chibar2=0.000	

*** Significant at 1%; ** significant at 5%; *significant at 10%

IV. CONCLUSION

Based on the study findings, the farmers are operating with substantial inefficiency and hence have a considerable yield potential of 34.51% to be exploited. The average EE efficiency index indicates that farmers could raise the profitability of rice production by 46.68% all these by fully adjusting input use. Furthermore, the major factors affecting economic efficiency in rice production are Soil fertility status, access to credit, household size and farmer experience were the factors that influenced the efficiency levels. It is recommended that for improved efficiency levels there is need for better policies and strategies for good soil fertility management options and farmer field schools that can offer training base for farmers. There is also need for policies aimed at reducing farmer's non-access to credit and ensuring that it is accessed at the right time to ensure appropriate use of the credit. There is needed to encourage rice farmers to work in groups so that they share experiences in rice farming which can assist those with limited experience to speed up in gaining the lacked experiences. Policies and other educational activities aiming at encouraging farmers to have reasonable household size are fundamental in reducing economic inefficiency.

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