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Determinants of rice efficiency in the upper east region of Ghana

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Abstract

Ghana's Upper East Region is one of the nation's major rice producing areas, but its production has declined in the past six years. This declining trend poses a threat to food security in the country. This paper identifies the factors that influences the efficiency of two rice producer groups in the region. The first group practiced irrigation with NGO support, and the other group, which is ubiquitous in the region, engaged in rainfed agriculture. Through multiple-stage sampling, we obtained 150 smallholder farmers. To determine the factors affecting rice efficiency in the region, the Cobb-Douglas Production Function was applied. The Ordinary Least Square regression results showed that land size, amount of fertilizer applied, and size of farmers' household had significant impact on their efficiency. This paper then makes some recommendations to improve rice farming in the region.

Introduction

Rice has become one of the most important staple crops in many African countries, especially in West Africa, Madagascar, and Egypt. According to the 2007 Africa Rice Trends by the Africa Rice Center, average paddy rice production in West Africa tripled from the 1970s to 2006. Along with Nigeria, Côte d'Ivoire, Mali, and Guinea, Ghana has been one of the most prominent rice producers in West Africa (Ghana Open Data Initiative, 2019), but the growth rate of rice yield has appeared to be stagnant for some years (Africa Rice Center [WARDA], 2007).

To attain self-sufficiency, the Ghanaian government has attempted to increase rice production, but this prospect appears to be unrealistic partly due to its slow growth in production (Ghana Open Data Initiative, 2019). The Upper East Region was one of the leading rice production areas, but it has experienced a decline in rice production for the past six years (Ghana Open Data Initiative, 2019). Many local farmers claimed that more frequent flooding, which has been caused by the spillage from Bagre Dam in Burkina Faso, was the main reason for the decline.

In our field investigation, however, we found that all flooded areas did not appear to be negatively affected. In fact, in the Northern and the Upper West Regions, which had similar flooding occurrences to the ones in the Upper East Region, rice production increased. We suspected that, other than upper stream spillage, there might have been other factors that affected rice production. This paper, therefore, seeks to identify the factors that determines rice production efficiency in the region.

Literature Review

D' Eça (1992) defined efficiency as the ability of a farmer to produce the maximum output from available resources. However, factors that define production efficiency have widely varied in past studies. These factors included land size, amount of applied fertilizer, seed availability, household size, labor, age, education, farming experience and extension service visits. Oyewo and Fabiyi (2008), for example, focused on land size and labor availability to examine Nigeria's maize

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farmers` efficiency in the Ogbomoso agricultural zone of Oyo State. They found a positive and significant relationship between land size and maize output. Singh (1992) found correlations between production and several factors such as land size, fertilizer and the adoption of high yield variety among those farmers who participated in an intensive agricultural program (1960–1961) at Aligarh district of India. Bojnec and Latruffe (2009) found significantly positive correlations between farm production efficiency and labor availability among Slovenian farmers.

Some studies focused on education and farming experience. Gebrehiwot (2017) showed the positive impact of agricultural extension services on farmers' efficiencies in Ethiopia by sampling 362 agricultural extension service participants and 369 farmers in northern Ethiopia. A study on farm level efficiency in small-scale swamp rice production in Nigeria by Idiong (2007) argued that educational level significantly influenced farmers' efficiency. However, Kalirajan (1981) argued that although schooling influenced productivity, farmers' education was not necessarily related significantly to their yield achievement. Illiterate farmers could understand modern production technology as well as their educated counterparts.

Overall, past studies tended to focus on specific factors in understanding the production efficiency of farms. Some wanted to find the impact of land and labor while others looked only at education or extension services. In the following discussion about our research result, we attempt to follow the factors D'Eca identified in order to better understand how these factors determined rice efficiency in the Upper East region of Ghana.

Methodology

The Study Area

To identify the production efficiency of Ghanaian farmers in connection to the above identified factors, Kassena-Nankana Municipality was selected as the study area. This municipality has a prominent rice production area in the Upper East Region. According to the 2010 Ghana population and housing census, Kassena-Nankana Municipality had a total population of 109,944 (about 19,790 households), representing 10.5 percent of the Upper East Region. Males constituted 48.8 percent. The average household size in the municipality was 5.4 persons per household. About 72.7 percent of the population lived in rural areas. Children constituted the largest proportion of the household, accounting for 44.7 percent. Couples without children constituted 9.7 percent. Extended households constituted 40.2 percent (Ghana Statistical Service, 2014).

The municipality's territory shares boundaries with Kassena-Nankana West District and Burkina Faso. The proximity to Burkina Faso was partly in response to farmers' claim about the negative impact of upper stream spillage on rice production. In the municipality, 82.7 percent of households engaged in agriculture while the rest mainly engaged in trading, food processing and small-scale artisanal works. In rural areas of the municipality, 93.1 percent of households engaged in agriculture while 56.8 percent of urban households engaged in the same sector. Most households in the municipality (96.1%) cultivated crops and raised chickens.

Data Collection

The data were collected mainly through the questionnaire survey and field observation. The field observation and the survey were conducted for the 2015–2016 cropping season. The respondents were rice farmers. The multi-stage sampling technique was used in selecting the respondents in five communities. Information was collected from 75 smallholder rice farmers who practiced irrigation farming and 75 rainfed rice farmers.

The questionnaire was divided into two parts. The first part was to identify the socio-demographic characteristics of the respondents such as age, gender, household size, education, extension officers' visits, and farming experience. The second part of our questionnaire sought to collect information about production efficiency factors, such as farm size, years of land use, amount of applied fertilizer (in bags) and seeds, the number of hired laborers, cost of land, the cost of fertilizer, seeds and laborers.

Data Analysis

The Cobb-Douglas production function

To determine the factors affecting rice production efficiency among the respondents, the Cobb-Douglas Production Function was applied. In past studies on agricultural production in Africa, several researchers used the Cobb-Douglas production function to identify factors affecting production efficiency. For example, Bidzakin, Fialor, and Asuming-Brempong (2014) applied this function to measure the production efficiency of 144 small-scale maize farmers across the three northern regions of Ghana. Using the multi-stage sampling method, the authors found that education, farming experience and household size had significant impact on their efficiency. In eastern Ethiopia, Seyoum, Battese, and Fleming (1998) investigated the efficiency of two maize farmer groups by using this model. The authors found that age, education, extension officers' visits significantly affected the efficiency. Again, a similar study examined the performance of maize farmers in Osun State, Nigeria. Using Cobb-Douglas Production Function, the author found that land size, labor, quantity of fertilizer applied, and level of education were significant factors affecting the output of maize in Nigeria (Oluwafunmilola, 2015).

The Cobb-Douglas production function is defined as Equation (1):

$$Q = P * A^{\wedge\beta 1} * L^{\wedge\beta 2} * S^{\wedge\beta 3} * F^{\wedge\beta 4} * Ex^{\wedge\beta 5} * G^{\wedge\beta 6} * H^{\wedge\beta 7} * Ed^{\wedge\beta 8} * Ep^{\wedge\beta 9} \quad (1)$$

Where Q denotes rice output; P is efficiency; A is the land size; L is the number of hired laborers; S is the amount of seed; F is the amount of applied fertilizer; Ex is the number of extension service visits; G is age of the respondents; H is household size; Ed is educational level; and Ep is years of farming experience (Hasan, Kamil, Mustafa, & Baten, 2012).

However, in order to estimate the factors determining rice output, the above function was transformed into a linear form since the variables in the Cobb-Douglas production function are not linearly related. This function was transformed into the ordinary least square regression model by using the basic mathematics natural logarithm rule (Equation (2)):

$$\text{Ln}(Q) = \text{Ln} P + \beta1^* \text{Ln}(A) + \beta2^* \text{Ln}(L) + \beta3^* \text{Ln}(S) + \beta4^* \text{Ln}(F) + \beta5^* \text{Ln}(Ex) + \beta6^* \text{Ln}(G) + \beta7^* \text{Ln}(H) + \beta8^* \text{Ln}(Ed) + \beta9^* \text{Ln}(Ep) \quad (2)$$

Here, Ln (Q) = Y (Dependent Variable); Ln P = $\beta0$; Ln (A) = X_1; Ln (L) = X_2; Ln (S) = X_3; Ln (F) = X_4; Ln (Ex) = X_5; Ln (G) = X_6; Ln (H) = X_7; Ln (Ed) = X_8 and Ln (Ep) = X_9.

The ordinary least square regression analysis was then carried out to establish the relationship between farmers' production efficiency. This analysis was done separately for irrigation farmers and rainfed farmers to understand the factors affecting each production.

Results and Discussion

Socio-Demographic Characteristics of Farmers

Table 1 shows the descriptive statistics of respondents' socio-demographic characteristics. The average mean ages for both rainfed and irrigation farmers were 47 and 48 years old respectively. The average household size in the study area was 10 persons, of which four were children. The respondents were educated up to junior high school level. This is lower than the national average for farmers in the 2010 national population and housing census survey.

In Ghana, extension officers under the Ministry of Food and Agriculture are normally expected to visit farms in their operational area at least three times a week. However, the respondents received extension services only twice a year. Without much professional knowledge transfer, the respondents relied on seven to nine workers to cultivate three to four acres of their farmland. This number of laborers is low compared to what is widely expected in this region. Most respondents used their children as laborers. The t-statistic values showed a significant difference between household size, household members involved in rice farming and education of the respondents in the study area ($p < .05$).

Factors Affecting Irrigation Farms' Production Efficiency

Table 2 shows the ordinary least square regression results of irrigation farmers' input variables on production. From the analysis, we observed that the coefficients of land size, fertilizer and household size were at 5 percent level of significance, with values of 1.033, -0.037 and 0.025. This indicates that 103 percent of land, 4 percent of fertilizer and 3 percent of household size explained the output of the responding irrigation farmers.

The coefficients of land size and household size showed a positive sign whereas the coefficient of fertilizer showed a negative sign. Positive coefficient indicates that irrigation farmers, who had a large household size and land size, were more efficient or productive. The negative coefficient on the other hand indicated that those farmers who used a smaller amount of fertilizer were more efficient than those who applied a larger amount. Table 2 also shows that the estimated R (0.92) is significantly different from zero. This result corresponds with the study by Singh (1992) who found a significant influence of land and fertilizer on maize output in India.

Table 1 Description of Respondents' Socio-Demographic Characteristics

Farmers	Irrigation		Rainfed		*t*
	Mean	Standard Deviation	Mean	Standard Deviation	
Age	48	10.960	47	11.050	0.740
Land Size (acre)	4	2.080	3	2.230	0.760
Years of Land Use	15	8.130	13	7.770	1.060
Household Size	10	5.560	10	6.220	-0.040*
Number of Children in Household	4	2.710	4	2.470	1.500
Household Members Engaged in Farming	5	2.340	6	2.830	-0.420*
Number of Hired Labor	9	4.830	7	3.520	1.500
Years of Schooling	7	4.820	7	4.700	-0.140*
Extension Service Contact (number of times a year)	2	1.080	2	1.010	0.770

*p-value < 0.05

Table 2 Ordinary Least Square Regression Analysis Results on Irrigation Farms

Variables	Parameters	Coefficients	Standard Error	*p*
Intercept	β0	23.050	11.129	.042
Land	β1	1.033	0.064	5.30E-24
Labor	β2	-3.252	1.870	.087
Seed	β3	0.105	0.622	.866
Fertilizer	β4	-0.037	0.110	.001
Extension Service	β5	0.103	0.061	.095
Age	β6	-0.361	0.218	.104
Household Size	β7	0.025	0.0593	.001
Education	β8	0.024	0.039	.540
Experience	β9	0.089	0.093	.340
R Square	R^2	0.920		
Significance F	F	8.03E-30		
Standard Error		0.220		
Number of Observations		74		

Factors Affecting Rainfed Farms' Production Efficiency

Table 3 shows the ordinary least square regression results of rainfed farmers' input variables on production. Somewhat similar to the results of irrigation farmers, we observed land size, the amount of applied fertilizer, and household size were significant with coefficients values of 1.104, 0.062 and -0.153. This implies that 6 percent of fertilizer, 110 percent of land and 15% of household size explained rainfed farmers' rice production. Land size and fertilizer coefficients were positive, but household coefficient was negative. This indicates that rainfed farmers who used relatively large areas of land and applied a sufficient amount of fertilizer tended to be more efficient or productive. Also, those rainfed farmers with small household size tended to be more efficient. This result is contrary to studies by Idiong (2007) and Kalirajan (1981), who found that the level of education significantly influenced the efficiency of farmers.

Interestingly, we suspected the existence of some econometric problems such as multicollinearity, heteroscedasticity and serial correlation in our OLS regression analysis for both irrigation and rainfed farmers. The significance *F*-value, which measures the significance of the entire regression analysis, was highly significant for the two producer groups. However, p-values of the independent variables for the two rice producer groups were insignificant.

Considering this finding, the following three hypotheses between independent variables of the two rice producer groups were tested:

Hypothesis 1: Multicollinearity exists between independent variables of irrigation farmers and rainfed farmers.

Hypothesis 2: Heteroscedasticity exists between independent variables of irrigation and rainfed farmers.

Hypothesis 3: Serial Correlation exists between independent variables of irrigation and rainfed farmers.

Table 3 Ordinary Least Square Regression Analysis Results on Rainfed Farmers

Variables	Parameters	Coefficients	Standard Error	*p*
Intercept	β0	25.853	15.573	0.101
Land	β1	1.104	0.082	3.85E-20*
Labor	β2	-3.289	2.652	0.219
Seed	β3	-0.589	0.715	0.414
Fertilizer	β4	0.062	0.081	0.001*
Extension Service	β5	-0.012	0.060	0.844
Age	β6	0.023	0.217	0.915
Household Size	β7	-0.153	0.056	0.001*
Education	β8	0.034	0.036	0.339
Experience	β9	-0.010	0.093	0.340
R Square	R^2	0.920		
Significance F	F	7.52E-30		
Standard Error		0.230		
Number of Observations		74		

$^*p < .05$.

Table 4 Breusch Pagan Test Results of Irrigation Farmers

Variables	Parameters	Coefficients	Standard Error	*p*
Intercept	β0	-0.436	0.906	0.632
Land	β1	-0.003	0.010	0.757
Labor	β2	0.001	0.002	0.730
Seed	β3	0.002	0.001	0.272
Fertilizer	β4	-0.034	0.020	0.070
Extension Service	β5	-0.002	0.008	0.826
Age	β6	-0.002	0.001	0.847
Household Size	β7	-0.001	0.002	0.419
Education	β8	-0.001	0.002	0.667
Experience	β9	3.37E-05	0.002	0.983
R Square	R^2	0.090		
Significance F	F	0.703		
Standard Error		0.066		
Number of Observations		74		

Multicollinearity Results between Independent Variables

To test for multicollinearity, correlation analysis between independent variables for the two rice producer groups was run. The results showed no multicollinearity existed between independent variables for the two groups. The first hypothesis was therefore rejected. However, collinearity existed between land and labor for both rainfed and irrigation farmers.

Results for Heteroscedasticity Test

To test for heteroscedasticity, the Breusch-Pagan test and White test approach were employed.

For Breusch-Pagan test, we regressed the square of the residuals on all the independent variables from the regression model for the two rice producer groups (Gujarati & Porter, 2009). Residuals are values derived by subtracting the predicted values from the actual values of our regression model.

From the results, the significance F-value ($F > 0.05$) indicated the non-existence of heteroscedasticity in the regression model for irrigation farmers (Table 4). However, the significance F-value ($F < 0.05$) obtained from the regression model for rainfed farmers indicates the presence of heteroscedasticity (Table 5).

To further confirm the presence of heteroscedasticity in rainfed farmers regression model, the White test was conducted. For the White test, we regressed the square of the residuals on the predicted rice output and the square of the predicted rice output (Gujarati & Porter, 2009).

The results from White test regression analysis showed no existence of heteroscedasticity in the regression model for rainfed farmers with significance F-value of 0.437 (Table 6).

Based on the above findings, the second hypothesis was rejected.

Serial Correlation Test Results

To test for serial correlation in our regression model, the Durbin-Watson Statistic was employed. The Durbin-Watson statistic is derived by dividing the sum of squared difference of residuals by the sum of squared residuals. No serial correlation exists when the Durbin-Watson statistic value equals 2 or approximately equals 2. There exist a positive and negative serial correlation when the value is less than or greater than 2 (Bhargava, Franzini, & Narendranathan, 1982).

The Durbin-Watson statistic values for the two rice producer groups were 1.74 and 1.98 respectively (Table 7). However, it was concluded that no serial correlation exists since the values are approximately equal to 2. Based on these findings, the third hypothesis was rejected.

Table 5 Breusch Pagan Test Results of Rainfed Farmers

Variables	Parameters	Coefficients	Standard Error	p
Intercept	β0	-0.637	1.010	0.531
Land	β1	-0.007	0.011	0.520
Labor	β2	0.003	0.002	0.230
Seed	β3	-0.004	0.002	0.016
Fertilizer	β4	-0.032	0.020	0.125
Extension Service	β5	-0.005	0.009	0.577
Age	β6	-0.000	0.002	0.794
Household Size	β7	0.005	0.002	0.002
Education	β8	-0.002	0.002	0.324
Experience	β9	-0.001	0.002	0.545
R Square	R^2	0.286		
Significance F	F	0.007		
Standard Error		0.073		
Number of Observations		74		

Table 6 White Test Results of Rainfed Farmers

Variables	Parameters	Coefficients	Standard Error	p
Intercept	β0	-0.061	0.190	0.750
Predicted Output	β1	0.044	0.113	0.696
Square of Predicted Output	β2	-0.004	0.016	0.807
R Square	R^2	0.023		
Significance F	F	0.437		

Table 7 Durbin-Watson Statistics Results

Variables	Irrigation Farmers	Rainfed Farmers
Sum of Squared Difference of Residuals	5.367	6.587
Sum of Squared Residuals	3.078	3.317
Durbin-Watson Statistic	1.74	1.986

Conclusion

This paper examined the factors that influenced rice production efficiency in the Upper East Region of Ghana. In doing so, we tried to understand why rice production in this region recently declined. We wanted to find what factors affected the decline other than frequent flooding, that some local farmers had claimed. The results of our investigation showed that land size, fertilizer and household size mainly affected the recent rice production decline in the region. On this, we did not observe significant discrepancies between rainfed farms and irrigation farms. Also, we found that multicollinearity did not exist between independent variables among the respondents.

Regarding land size, our field observation found that smallholder farmers in the study area faced difficulties in obtaining a large area of farmland for rice production largely because of the existing dual and somewhat conflicting land tenure system between modern legal ownership and traditional ownership. Under customary land tenure practices, women farmers cannot have equal access to farmland even though women tend to be the main rice farm laborers. Also, the amount of applied fertilizer being the main influencing factor meant that the soil of rice farms requires regular fertilization to maintain productivity. So far, the Ghanaian government has not done much to support farmers to buy fertilizer even though farmers in the region are relatively poor. A very low frequency of extension officers' visits at these farms also showed insufficient technical support for the responding farmers.

Conflict of Interest

There is no conflict of interest.

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