



Energy-Use Efficiency of Rice Production Under Irrigation in Jere Bowl Borno State, Nigeria

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Abstract: The study analyzed energy-use efficiency of irrigated rice production at the jere bowl of Borno state, Nigeria. One hundred and thirty (130) farmers were sampled through two-stage sampling procedure. Descriptive statistics, data envelopment analysis and tobit regression were used to analyzed the data. The results on energy–use efficiency revealed scores of 0.444, 0.948 and 0.462 for technical efficiency, pure technical efficiency and scale efficiency respectively. Moreover, the saving energy estimated showed 8.02% of the percentage of total saving energy over total actual use in optimum requirement. This indicates that about 2711.21MJ/ha of total input energy could be saved while holding the constant output level of rice. The coefficients Of age, years of formal education, years of farming experience, number of household, farms size and access to credit were significant and positively related to energy-use efficiency in rice production. The study recommended that farmers should use the optimum quantity of energy inputs resulted from this study because about 2711.21MJ/ha of energy could be saved while maintaining the same output thereby improving their efficiency.

Keywords: Optimum Quantity, Saving Energy, Tobit Regression, Energy-Use and Jere Bowl

1. Introduction

Rice is a very important food crop in the world because is the second largest cereal consumed after wheat which provides staple food for more than half of the world's population with about 80% of its food calorie requirements [1]. Nigeria is the largest producer of rice in West Africa but second largest importer in the continent, accounting for 25% of continent's imports. The local production is done on 2.8 million hectares of farm land with a total production of 2.8 million metric tons of the estimated 6.1 million metric tons it consumes annually [2]. Agriculture generally, is closely linked with energy as it consumes and produces energy in form of biomass. For production to take place, energy inputs must be used. The resource inputs used in rice production such as seed, fertilizer, labour, water for irrigation and agrochemicals contains energy which is called energy inputs. The energy input is one of the key factors for successful rice production. Use of energy input in rice production has been

increasing in response to population growth, limited arable land, and a desire for higher standards of living [3].

Rice production incurs much higher input of energy, mainly due to its high water and fertilizer requirements coupled with other practices like transplanting, harvesting and threshing. It was estimated that the tillage operations, fertilizers and pesticides constitute about 70% of the energy required for rice production while fertilizer alone accounted for about 40%. Amongst fertilizers, nitrogen accounted for maximum energy input in rice production [4]. Continuous demand for increased rice production has resulted in intensive use of these energy inputs. Due to farmers inadequate knowledge and few incentives to use more energy efficient methods, over usage of this energy input may cause a serious threat to environment which might compromise sustainability. There is need for effective planning for the use of these energy inputs in the process of rice production to achieve energy-use efficiency. Energy-use efficiency entails the use of the appropriate amount of energy input in

production in the right form and at the right time which is helpful in achieving sustainable rice production [5].

Jere bowl Borno state is known for rice production and it has a cultivable land area of about 22,000 ha, out of which a gross area of 15,850 ha was identified as suitable for irrigated agriculture [6]. This area is capable of producing about 32,000 tons of rice annually. Rice produced in jere bowl is marketed all over Nigeria and contributes greatly to the thriving cross-border trade between Nigeria, Chad, Niger and Cameroon [7]. The extent to which rice production in the jere bowl is energy-efficient and sustainable to ensure continuous increased output and to ensure the survival of future generation is thus far unknown. This study aims to unravel this information.

Similarly, not much attention has been given to the study of energy-use efficiency in crop production in Nigeria. The increasing demand for food production (particularly rice) from an ever-increasing population and the dwindling nature of natural resources such as water as a result of their continuous and excessive use coupled with the effect of climate change makes the study on energy-use efficiency and sustainability of rice production very important. While rice farmers are energy-efficient, their productivity will be sustainable. Therefore it was against this background that the study seeks to answer the following questions;

- i. Is energy efficiently utilized in rice production in the study area?
- ii. What is the socioeconomic factors influencing energy-use efficiency of rice production in the study area?

The main objective of the study was to analyse the efficiency of energy-use in rice production under irrigation in Jere Bowl Borno State, Nigeria.

The specific objectives were to:

- i. determine the energy-use efficiency of rice production in the study area and
- ii. examine the socioeconomic factors influencing energy-use efficiency of rice production in the study area.

2. Methodology

2.1. Study Area and Data Collection

The study was conducted in Jere bowl Borno State, Nigeria. It lies between latitudes 11° 40' and 12° 05'N and longitudes 13° 05' and 12° 20' E with a projected population of 270, 344 persons in 2016 based on 2.8 population growth rate [8]. Jere Bowl has a cultivable land area of about 22,000 ha, out of which a gross area of 15,850 ha was identified as suitable for irrigated agriculture [6]. The climate of the area is dry and hot for most part of the year with minimum temperature ranging from 15-20°C and maximum range of 37-45°C. The annual rainfall ranges from 500mm to 700mm characterized by high variability and intensity. The rainy season usually last from May to September with a relatively low humidity [9]. This is followed by a long dry season. The major river in the area is the Ngadda River which flows through Alau Dam where overbank flows occur. This resulted in the formation of the Jere Bowl [10], which is

generally referred to as Fadamas in Hausa language, meaning lowland, floodplain, and valley-bottom around a river.

Both primary and secondary data was used for this study. The primary data were collected with the aid of well-structured questionnaire which was administered to the respondents. The data was collected on the rice farm input (such as seed, fertilizer, labour, water, Pesticides and fuel) and farm output (rice grain and straw). A total of 130 farmers were selected from four purposively selected communities using multi-stage sampling technique. The list of the rice farmers was obtained from the functional rice farmers associations of Jere bowl Borno state. The sample equation was used to determine the number of respondents from each of the community and was expressed as follows:

$$n = \frac{N}{N + 1(\alpha)2}$$

Where:

n = Sample size

N = Population

α = Confidence interval

2.2. Analytical Techniques

The analytical techniques used were descriptive statistics such as frequency and percentages, and inferential statistics such as energy equations, Data Envelopment Analysis (DEA) and Tobit regression model.

The energy equivalents in Table 2.1 were used with equation 1, 2 and 3 to convert the physical amount of inputs and outputs to energy forms expressed in MJ/ha.

Following [11], [12] and [13], the equations are given as.

2.2.1. Labour Energy

The energy of labour in the production was estimated using the following equation;

$$\text{Lab.} = \frac{\text{lb.T.Lf}}{A} \tag{1}$$

Where:

Lab = Energy of labour (mj/ha)

Lb = Number of working labourers (No)

T = Operating time (h)

Lf = equivalent energy of labour (mj/h)

A = Area covered (ha)

Table 1. Equivalent Energy Conversion Factors.

Energy use	Energy Coefficient (MJ/unit)	Sources
Human Labour (h)	1.96 MJ/h	[14]
Seed	17.5MJ/Kg	[3]
Fertilizer (Kg)		
Nitrogen	60.60 MJ/Kg	[14]
Phosphorus	11.10 MJ/Kg	[14]
Potassium	6.70 MJ/ Kg	[14]
Pesticide (Kg)		
Insecticide	199 MJ/Kg	[14]
Fungicide	92 MJ/Kg	[14]
Herbicide	238 MJ/Kg	[14]
Paddy (Kg)		
Grain	14.57 MJ/kg	[15]

Energy use	Energy Coefficient (MJ/unit)	Sources
Straw	12.50 MJ/ Kg	[15]
Water (M ³)	0.63 MJ/M ³	[14]
Fuel (L)		
Petrol	37MJ/L	[16]
Diesel	56.31MJ/Kg	[14], [17] and [18]

2.2.2. Energy of Water

The energy of water used during irrigation in rice production, was determined using the following equation:

$$EW = \frac{DC.T.F.Eqf}{A} \tag{2}$$

Where:

- EW = Energy of water (MJ/ha)
- DC = Discharge capacity of the water pump (m³/min.)
- T = Time of water application (Min/application)
- F = Frequency of application (Number of time)
- Eqf = Energy Equivalent for water (MJ/M³)
- A = Area applied (ha)

2.2.3. Energy Per Unit Area for Other Production Inputs

Such as fertilizer, fuel, pesticides and seed as well as the energy output was expressed as;

$$EID = RATE. MATENF \tag{3}$$

Where:

- EID = Energy inputs (Mj/ha)
- RATE = Application rate of Input (unit/ha)
- MATENF = Energy equivalent of input (Mj/unit)

2.2.4. Data Envelopment Analysis (DEA)

Linear programming using data envelopment analysis (DEA) models was employed to determine energy-use efficiency of rice production. The DEA models deployed in this study were Charnes, Cooper and Rhodes (CCR); Banker, Charnes, and Cooper (BCC). The CCR DEA model assumes constant returns to scale. It measures the technical efficiency by which the DMUs are evaluated for their performance relative to other DMUs in a sample [19]. The BCC DEA model assumes variable returns to scale conditions. It calculates the technical efficiencies of DMUs under variable

$$\text{Scale efficiency} = \text{technical efficiency} / \text{pure technical efficiency} \tag{6}$$

2.2.5. Tobit Regression

Tobit regression was used to determine the socioeconomic factors influencing energy use efficiency of rice production. The model is implicitly expressed as:

$$\ln Y = B_0 + B_1 \ln X_1 + B_2 \ln X_2 + B_3 \ln X_3 + \dots + B_8 \ln X_8 + e \tag{7}$$

Where:

- Y = Efficiency scores (ranges from 0-1)
- X₁ = Age (years)
- X₂ = Sex (1- male, 0 – female)
- X₃ = Level of education (years spent in school)
- X₄ = Household size (Number of person)
- X₅ = Farm income (₦)
- X₆ = Farm size (ha)
- X₇ = Farming Experience (years)

return to scale conditions. It decomposes the technical efficiency into pure technical efficiency for management factors and scale efficiency for scale factors [20].

Following [21], the CCR model is explicitly expressed as:

$$\begin{aligned} \text{Max } Ep &= \sum_{r=1}^{r=s} Ur. Yrp \\ \sum_{i=1}^{i=m} Vi. Xip &= 1 \end{aligned} \tag{4}$$

$$\sum_{r=1}^{r=s} Ui. Yrj - \sum_{i=1}^{i=m} Vi. Xij \leq 0, j = 1, 2, \dots, n$$

$$Vi \geq \epsilon,$$

$$Ur \geq \epsilon$$

While the BCC model is explicitly expressed as;

$$\begin{aligned} \text{Max } Ep &= \sum_{r=1}^{r=s} Ur. Yrp + w \\ \sum_{i=1}^{i=m} Vi. Xip &= 1 \end{aligned} \tag{5}$$

$$\sum_{r=1}^{r=s} Ui. Yrj - \sum_{i=1}^{i=m} Vi. Xij + w \leq 0, j = 1, 2, \dots, n$$

$$Ui \geq \epsilon, Vi \geq \epsilon, w \text{ free}$$

Where:

- E_p = Energy productivity (ith unit efficiency ratio)
- X_{ip} = Quantity of ith input for ith DMU_p
- Y_{rp} = Quantity of r output for ith DMU_p
- U_r = Weight of inputs (mj)
- V_i = Weight of output (mj)
- J = 1, 2, ..., n
- S = Number of decision making unit (No.)
- m = Number of output (No.)

The efficiency of CCR model is called technical efficiency (equation 9 above), as it is not under the effect of scale and size. On the other hand, BCC shows pure technical efficiency (equation 5 above) under the effect of efficiency to variable scale. The relation among technical efficiency, pure technical efficiency and scale efficiency is defined as follows [22]:

3. Results and Discussion

3.1. Energy Use Efficiency of Rice Producers in Jere Bowl

The results of energy-use efficiency were presented in

- X₈ = Access to credit (Dummy = 1 if a farmer has access and 0 otherwise)
- e = Error term

Table 2. The table revealed that the average values of technical, pure technical and scale efficiency scores were 0.444, 0.948 and 0.462, respectively. This implies that there is room for improvement by 56%, 5% and 54% in their technical, pure technical and scale efficiencies respectively. Moreover, the technical efficiency varied from 0.431 to 1.0, with the standard deviation of 0.318, which was the highest variation between those of pure technical and scale efficiencies. The wide variation in the technical efficiency of farmers implies that the farmers were inefficient in their energy use. This could be attributed to the fact that most of the farmers were not fully aware of the right production techniques or did not apply them at the proper time in the optimum quantity or may not have the financial means to procure the right inputs. Similar results were reported by [23] in their studies of the efficiencies of farmers in kiwifruit production. They reported that, the technical, pure technical and scale efficiency scores were as 0.442, 0.993 and 0.448, respectively.

Table 2. Energy use Efficiency of Rice Producers in Jere Bowl Borno State.

Particular	Average	SD	Min.	Max.
Technical Efficiency	0.444	0.318	0.431	1
Pure technical Efficiency	0.948	0.223	0.642	1
Scale Efficiency	0.462	0.301	0.861	1

Source: Computed From Field Survey, 2017.

3.2. Actual, Optimum and Saving Energy for Rice Production in Jere Bowl

Table 3 shows the optimum energy requirement and saving energy for rice production based on the results of BCC model. Also, the percentage of energy saving are illustrated in the last column. As indicated, optimum energy requirement for irrigation water (16517.35 MJ/ha) was found to be the highest.

Also, the optimum values of seed, human labor, N fertilizer, P fertilizer, K fertilizer, herbicide, insecticide and fuel energy inputs were estimated at 2569.71MJ/ha, 960.17MJ/ha, 4821.04MJ/ha, 113.57MJ/ha, 68.64MJ/ha, 502.33MJ/ha, 63.29MJ/ha, and 8074.55MJ/ha respectively. Moreover, the saving energy estimated showed that, 4.19% from seed, 56.48% from labour, 6.88% from water for irrigation, 53.57% from chemical fertilizer, 64.15% from pesticides and 6.28% from fuel energy consumption could be saved.

The percentage of total saving energy in optimum requirement over total actual use of energy was calculated as 8.02%, indicating that by using the optimum inputs' quantity resulted from this study, on average, about 2711.21MJ/ha of total input energy could be saved while holding the constant output level of rice yield. These findings are similar to [24] who reported that about 5901.31 MJ/ha of total input energy could be saved while holding the constant output level of Corn yield.

Table 3. Actual, Optimum and Saving for Rice Production.

Energy input	Actual Energy (MJ/ha)	Optimum Energy (MJ/ha)	Saving Energy (MJ/ha)	Saving Energy%
Seed	2677.50	2569.71	107.79	4.19
Labour	1502.51	960.17	542.34	56.48
Water	17654.54	16517.35	1137.19	6.88
Nitrogen	4973.40	4821.04	152.36	3.16
Phosphorus	168.51	113.57	54.94	2.03
Potassium	101.71	68.64	33.07	48.38
Herbicide	646.55	502.33	144.22	28.71
Insecticide	85.72	63.29	22.43	35.44
Fuel	8581.42	8074.55	506.87	8.02

Source: Computed From Field Survey, 2017.

3.3. Influence of Socioeconomic Factors on Energy-Use Efficiency of Rice Production

Many of the variables were found to influence energy use efficiency of rice production in the Jere bowl of Borno state. Out of the eight variables analyzed, seven were found to influence efficiency positively and were found to be statistically significant at various levels of significance as shown in Table 4. These variables include age, educational level; number of years of experience in rice farming, household size, farm size, and access to credit of the farmers. This implies that increasing use of these factors in the rice production processes would improve technical efficiency of rice production. The coefficient of age (0.316) of the farmer was positive and significant ($p < 0.01$) implying that 1% increase in the age of the farmer leads to 0.3% increase in the level of energy-use efficiency (table 4). This is probably due to the fact that as farmers grow old they gain more

experience in the production of various agricultural practices; hence they become more efficient.

Table 4. Socioeconomic Factors Influencing Energy-use Efficiency of Rice Production.

Variable	Coefficient	Standard Error	T-value
Constant	0.248	0.073	3.39***
Age	0.316	0.011	27.67***
Sex	0.008	0.010	0.85 ^{NS}
Education	0.887	0.040	2.20**
Household Size	0.067	0.027	2.50***
Farm Annual Income	0.069	0.034	2.02**
Farm Size	0.810	0.326	2.49**
Farming Experience	0.851	0.231	3.69***
Access to Credit	0.025	0.011	2.30**

Source: Computed From Field Survey, 2017

*** Significant at 1%, ** Significant at 5% and NS Not Significant

This finding is in agreement with [25] who found age of

the farmers to have a positive influence on technical efficiency.

The coefficient of sex of the farmers (0.008) was positive but not significant indicating that sex of the farmers has no any influence on the energy-use efficiency of rice production in the study area. The coefficient of education (0.887) was found to be positive and significant ($p < 0.05$) indicating that the more educated the farmers are, the easier will be for them to understand and adopt improved practices to become energy-use efficient. This result is in agreement with the findings of [26] and [27] who reported that producers with high formal education levels (≥ 12 years) are able to detect and reduce inefficiency in production.

The coefficient of years of experience in rice farming (0.851) was positive and significant ($p < 0.01$), implying that as years pass with continuous rice farming, farmers tend to increase their capacity to do better in rice farming; hence, they become more energy-use efficient. Over time, the farmers are better placed to acquire more knowledge and skills necessary for choosing appropriate new farm technologies. These findings are in line with those of [28].

The coefficient of size of the household (0.067) was positive and significant ($p < 0.01$) implying that, as the household size increases the energy-use efficiency of rice production increased. Similar results were reported by [29] and [30] that household size positively influences technical efficiency. The coefficient of the farmers annual farm income (0.690) was positive and significant ($p < 0.05$) implying that farmers with increased farm income do attain some level of technical efficiency in their production as they can able to afford efficiency improving inputs. The coefficient of farm size (0.810) was positive and significant ($p < 0.05$) implying that 1% increase in the farm size of the farmer leads to 0.8% increase in the level of energy-use efficiency. This indicates that efficiency of rice production increases with size of land under rice. Similar results were reported by [31].

The coefficient of access to credit (0.252) was positive and significant ($p < 0.05$) implying that the more access farmers have to credit the more they will be technically efficient. This finding agrees with [31] that credit to the farmers may act as an instrumental motivation to produce more efficiently apart from being able to purchase the required inputs for efficient production.

4. Conclusion

An energy-use efficiency of irrigated rice production in Jere bowl Borno state, Nigeria was studied based on the level of energy use in the production. It revealed that technical efficiency; pure technical efficiency and scale efficiency scores were 0.444, 0.948 and 0.462, respectively. This indicates that the farmers were not energy-use efficient. Moreover, the saving energy estimated showed that about 2711.21MJ/ha of total input energy could be saved while holding the constant output level of rice yield when the optimum quantity of input is used.

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