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ENERGY USE ANALYSIS FOR RICE PRODUCTION IN NASARAWA STATE, NIGERIA

[ANALISIS DEL USO DE LA ENERGÍA PARA LA PRODUCCIÓN DE ARROZ EN EL ESTADO DE NASARAWA, NIGERIA]

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SUMMARY

The study was conducted to analyze energy use for in rice production in Nasarawa state Nigeria using a sample of 120 randomly selected rice farmers. Energy productivity, energy efficiency and specific energy were computed and simple descriptive statistics was used for data analysis. The energy use pattern shows that, rice production consumed an average total energy of 12906.8 MJha^{-1}, with herbicide energy input contributing the largest share (53.55 %). Human labour had the least share (0.74 %) of the total energy input used. The energy productivity, Specific energy and energy efficiency were 0.3 MJ^{-1}, 3.6 MJ^{-1} and 4.1 respectively. A total of 10925.0 MJ of energy was used in the form of indirect energy and 1981.8MJ was in the direct form of energy. Non-renewable energy forms contributed the largest share (80.63 %) of the total energy input used for rice production in the study area. Rice production in the study area was observed to be mainly dependent on non-renewable and indirect energy input especially herbicide. Thus, the study recommends the introduction of integrated weed management system in order to reduce cost and dependence on a non-renewable input for weed control.

Key words: Herbicide; Nigeria; renewable energy; rice; productivity.

RESUMEN

El estudio se llevó a cabo para analizar el uso de la energía para la producción de arroz en el estado de Nasarawa, Nigeria usando una muestra de 120 granjeros de arroz al azar. Se capturó la productividad energética, eficiencia energética y energía específica, se realizó un análisis descriptivo simple. El patrón de energía mostró que la producción de arroz consumió en promedio un total de energía de 12,906.8 MJha^{-1}, la energía del herbicida contribuyo grandemente (53.55%). La labor humana tuvo el menor consumo (0.74%) del total de datos usados. La productividad energética, la energía específica y la eficiencia energética fueron de 0.3 M^{-1}J, 3.6 MJ^{-1} y 4.1 MJ^{-1} respectivamente. Un total de 10925.0 MJ de energía fueron usados en forma indirecta y 1981.8 MJ se usaron en forma directa. Las formas de energía no renovable contribuyeron en gran medida (80.63%) del total de energía analizada en el área de producción. La producción de arroz observada en el área fue principalmente dependiente de la energía no renovable y hubo un ingreso especialmente alto del herbicida. Sin embargo, el estudio recomienda la introducción de un sistema de integral de manejo de malas hierbas para reducir los costos y dependencia de la energía no renovable.

Palabras clave: Herbicida; Nigeria; energía renovable; productividad; arroz.

INTRODUCTION

Energy is said to be the engine for growth and development in all economies of the world. In all parts of the world today, the demand for energy is increasing almost on a daily basis. According to Pimental (1992), energy is one of the most valuable inputs in agricultural production. Sufficient availability of the right energy and their effective and efficient uses are prerequisites for improved agricultural production (Handan *et al*. 2009). The amount of energy used in agricultural production, processing and distribution is significantly high in order to feed the expanding population and to meet other social and economic goals of a society (Handan *et al*. 2009). It has been realized that crop yield and food supplies are directly linked to energy availability or consumption. Also, increases in yields in the developed countries are as a result of commercial energy inputs, in addition to improved varieties (Tolga *et al*. 2009).

Energy use in agriculture has become more intensive as the Green Revolution led to the increasing use of high yielding seeds, fertilizers and chemicals as well as diesel and electricity. Energy consumption per unit area in agriculture is directly related to the development of the technology in farming and the level of production. Inputs such as fuel, electricity, machinery, seed, fertilizer and chemical take significant share of the energy supplies in the production system of modern agriculture. Thus, the use of intensive inputs in agriculture and access to plentiful fossil energy has provided an increase in food production and standard of living (Selim *et al*. 2005).

Rice is the second most important cereal in the world after wheat in terms of production (Jones 1995). Nigeria ranks the highest as both producer and consumer of rice in the West Africa sub-region (Jones 1995). However, in terms of area of land under food crop production in the country, rice ranks sixth (after sorghum, millet, cowpea, cassava and yam) (Imolehin and Wada 2000). The Federal Ministry of Agriculture (1993) estimated that the annual supply of food crops (including rice) would have to increase at an average annual rate of 5.9 % to meet food demand, and reduced food importation significantly. Studies have shown that aggregate rice production in Nigeria has been growing at about 2.5 % per annum in recent years (Olayemi 1998; Akinbola 2002; Amaza and Olayemi 2002). But the annual rate of population growth has been high (about 3 %) (Akinbola 2002). The reality is that Nigeria has not been able to attain self-sufficiency in rice production despite increasing hectares put into production annually. The constraint to the rapid growth of food production seems to be mainly that of low crop yields and resource productivity. The implication is that there is hope for additional increases of output from existing hectares of rice, if resources are properly harnessed and efficiently allocated (Amaza and Olayemi 2002).
Several studies have outlined a number of factors responsible for the low level of rice production in Nigeria (Kolawole and Scoones 1994; Atala and Voh 1994, Okuneye 2001). However, studies analyzing the relationship between energy inputs and rice yield in Nigeria are not available. There is a dearth of data on energy expenditure and returns in crop production in Nigeria, and other developing countries (Abubakar and Ahmed 2010). Even though, much attention is not given to the knowledge about energy expenditure in crop production in Nigeria, the increasing demand for food production to meet the pressure from an ever-increasing population makes the energy-agriculture relationship very important. For these reasons, energy use pattern, energy efficiency, energy productivity, specific energy and energy inputs-output relationship were determined for rice production in north central Nigeria.

MATERIALS AND METHODS

Nasarawa State is located in north central Nigeria. It lies between North Latitude 7^o and 9^o and 7^o and 10^o East Longitude and shares boundary with Benue State to the South, Kogi State to the west, the Federal Capital territory, Abuja to the North – East, Plateau State to the South east. The State covers an area of about 27, 117 Km^2 with an estimated population of 1,863,275 people (National Population Commission 2006). The State has a mean temperature range of 25^{o}C in October to about 36^{o}C in March while annual rainfall varies from 13.73mm in some places to 145mm in others. Alluvial soils are found along the Benue trough and their flood plains. The forest soils, which are rich in humus and laterite, are found in most part of the state. There are also sandy soils in some parts of the state. Solid minerals notable are salt and bauxite. A three (3) stage random sampling technique was used to determine the sample size. In the first stage, a zone from the three ADP zones (Nasarawa North, West and East) was randomly selected. In the selected zone (Nasarawa East), the list of major rice producing communities was obtained, and four communities. (Sabon-Gida, Assakio, Brum-brum and Awe) were randomly sampled. Finally, 30 rice farmers were selected from each community to give a sample size of 120 rice farmers for the study. Structured questionnaire administered to the respondents was used to collect data for the study. Data were collected on the socio-economic characteristics of the respondents as well as production inputs and output in rice production.
Simple descriptive statistics was used for data analysis; energy efficiency, specific energy and energy productivity, for rice crop production were also calculated on per hectare basis using the equations suggested in literature (Canakci *et al*. 2005; Ozkan et al. 2004; Hatirli *et al*. 2005; Singh and Mittal, 1992; Khan *et al*. 2004).

$$\text{Energy efficiency} = \frac{\text{Total energy output (MJ/ha)}}{\text{Total energy input (MJ/ha)}}$$

$$\text{Energy productivity} = \frac{\text{Rice yield/output (kg)}}{\text{Energy input (MJ/ha)}}$$

$$\text{Specific Energy} = \frac{\text{Energy input (MJ/ha)}}{\text{Rice yield/output (kg)}}$$

Each agricultural input and output has its own energy equivalent value. Hence the inputs and output were converted into their equivalent energy units using the conversion factors in Table 1.

Table 1. Energy equivalent for different input and output in rice production**.**

Input	**Energy equivalent (MJ/Unit)**	**Reference**
NPK fertilizer (kg)	11.76*	
Human Labour (Man hours)	01.96	Singh *et al.* (2002)
Chemical Insecticide (L)	199.00	Helsel (1992)
Chemical Herbicides (L)	238.00	Helsel (1992
Machinery (h)	62.70	Singh *et al*. (2002)
Diesel – Oil (L)	56.31	Singh *et al.* (2002)
Seed (kg)	14.7	Singh (2002)
Yield (kg)	14.7	Canackci *et al.* (2005)

*The energy equivalent for a kilogram of NPK fertilizer was derived from the ratio of the elements (N, P and K) in a 50 Kg bag of the fertilizer. The NPK 15:15:15 brand is the most widely used amongst the respondents in the study area. As such, for each element, its quantity in kilogram in a 50 Kg bag was determined as follows;

$$N = \frac{15}{100} \times \frac{50}{1} = 7.5$$

$$P = \frac{15}{100} \times \frac{50}{1} = 7.5$$

$$K = \frac{15}{100} \times \frac{50}{1} = 7.5$$

However, from literature, the energy equivalent for elemental N, P and K are as follows; 60.60 MJ, 11.10 MJ and 6.70 MJ respectively. Thus, the quantity of each element was converted to its energy equivalent as shown below.

N = 60.60 × 7.5 = 454.5 MJ
P = 11.10 × 7.5 = 83.25 MJ
K = 6.70 × 7.5 = 50.25 MJ
Total =588.00 MJ

This implies that a 50 Kg bag of NPK 15:15:15 fertilizer is equivalent to 588 MJ of energy, while a kilogram of the fertilizer is equivalent to 11.76 MJ of energy.

RESULTS AND DISCUSSION

Inputs and outputs level in rice production

The quantities of inputs/ha used and output/ha (paddy) obtained in rice production in the study area are presented in Table 2. To cultivate a hectare of rice in the study area, a total of 163.5 kg of seed, 48.7Man hours of labour, 105.2 kg of fertilizer, 29.0 L of herbicide, 0.5 L of insecticide, 33.5 L of diesel and 6.97 hours of machinery were used. These are equivalent to, 2403.5 MJ, 95.4 MJ, 1237.4 MJ, 9612.4 MJ, 110.4 MJ, 1888.4 MJ and 437 MJ of energy respectively. An average yield of 3597.93 kg/ha of paddy equivalent to 52889.1 MJ of energy was obtained.

The result obtained from this study shows that energy inputs used by the farmers in the study area were manual (human labour), chemical (fertilizer and diesel), mechanical (machinery), and biological (seed). The average quantity of seed, fertilizer and herbicides used per hectare were not in accordance with the recommended rates of 80 – 100 kg/ha for seed, 300 – 400 kg/ha for fertilizer and 16 – 20 L/ha for herbicide for rice production in Nigeria, (Ekeleme *et al.,* 2008).

Energy use pattern in rice production

The pattern of energy usage in rice production is presented in Table 3. The total energy input used per hectare for rice production was 12906.8 MJ. Human labour and herbicide contributed the minimum and maximum energy input values of 95.5 MJ/ha and 6913.9 MJ/ha respectively for rice production, representing 0.7 % and 53.6 % respectively of the total energy used per hectare. The observation for human labour can be attributed to the fact that human labour was only used for planting, fertilizer application and harvesting only. On the other hand, herbicide energy dominated the total energy input used because of its excessive usage for weed control in the study area. Insecticide, diesel and fertilizer inputs contributed 0.9 %, 14.6 % and 9.6% of the total energy inputs per ha respectively. The result indicated that, the energy efficiency and specific energy for rice production were 4.1 and 3.6 MJ^{-1} respectively, while energy productivity was 0.3 MJ^{-1}. The energy efficiency ratio of 4.1 indicates high energy use efficiency. However, the productivity of energy inputs was very low. This can be attributed to the usage of local rice varieties in the study area. The specific energy shows the amount of energy required to produce a kilogram of paddy. Thus, a specific energy of 3.6 means that 3.6 MJ of energy is required to produce a unit of paddy rice.

Energy productivity for various inputs in rice production

The energy productivity of inputs for rice production is presented in Table 4. The value of energy productivity for the inputs ranges from 0.5 to 37.7 for herbicide and labour respectively. Seed, insecticide, diesel, machinery and fertilizer inputs have productivity ratios of 0.9, 30.3, 1.9, 14.4 and 2.9 respectively. The result revealed that, human labour and herbicide were respectively the most productive and the least productive energy inputs for rice production in the study area.

Energy inputs in the forms of direct and indirect, renewable and non-renewable energy for rice production

The results in Table 5 shows that, non-renewable energy forms contributed 80.6 % of the total energy input for rice production, while only 19.4 % comes from the renewable energy forms. On the other hand, 84.7 % of the total energy is also in the form of indirect energy, with the direct energy forms contributing 15.3 % of the total energy. This finding implies that rice production in the study area is mostly dependent on non-renewable and indirect energy forms especially herbicides.

Table 2. Inputs/outputs level in rice production.

Units	Mean	Maximum	Minimum
Yield (kg)	3597.9	16000.0	1166.6
	(52889.1)	(235200.0)	(17150.0)
Seed (kg)	163.5	1000.0	33.3
	(2403.5)	(14700.0)	(490.0)
Human labour (Man hours)	48.7	270.0	7.5
	(95.4)	(529.2)	(14.7)
Fertilizer (kg)	105.2	500.0	35.0
	(1237.4)	(5880.0)	(411.6)
Herbicide (L)	29.0	120.0	09.0
	(6912.4)	(28560.0)	(2142.0)
Insecticide (L)	0.6	10.0	0.0
	(110.4)	(1990.0)	(0.0)
Diesel (L)	33.5	250.0	0.0
	(1888.4)	(14077.5)	(0.0)
Machinery (h)	6.9	60.0	0.0
	(437.03)	(3762.0)	(0.0)

Figures in parenthesis are the energy equivalents of the inputs in MJ

Table 3. Energy use pattern in rice production (ha).

Input	Quantity/unit area (ha)	Total Energy Equivalent	%
Human labour (Man hour)	48.7	95.5	0.7
Machinery (h)	4.0	250.8	1.9
Herbicide (L)	29.05	6913.9	53.6
Insecticide (L)	0.6	119.4	0.9
NPK Fertilizer (kg)	105.2	1237.4	9.6
Diesel (L)	33.5	1885.6	14.6
Seed (kg)	163.5	2403.5	18.6
Total Energy Input (MJ/ha	-	12906.8	100.0
Yield (kg)	3597.9	52889.1	
Energy Efficiency	-	4.1	
Energy Productivity	-	0.3 $KgMJ^{-1}$	
Specific Energy	-	3.6 $MJKg^{-1}$	

Table 4. Energy productivity for various inputs in rice production.

Inputs	Qty/ha	Energy equivalent	Energy productivity	Rank
Human Labour	48.7	95.5	37.7	1st
Machinery	4.0	250.8	14.4	3rd
Herbicides	29.05	6923.9	0.5	7th
Insecticide	0.6	119.4	30.1	2nd
NPK fertilizer	105.2	1237.4	2.9	4th
Diesel	33.5	1885.6	1.9	5th
Seed	163.5	2403.5	0.9	6th
Yield	3597.9	52889.6		

Table 5. Energy inputs in the forms of Direct and Indirect, Renewable and Non-renewable energy for rice production.

Energy forms	Total Energy equivalent(MJ/ha)	%
Direct Energy [a]	1981.8	15.3
Indirect Energy [b]	10925.0	84.7
Total	**12906.8**	**100.0**
Renewable [c]	2499.6	19.4
Non-renewable [d]	10410.2	80.6
Total	**12906.8**	**100.0**

a. Human labour, and Diesel, b. Fertilizer, Insecticides, Herbicides, Machinery and Seed, c. Human labour, Seed, d. Diesel, Fertilizer, Insecticides, Herbicides and Machinery

CONCLUSION

Rice production in the study area was observed to be mainly dependent on non-renewable and indirect energy input especially herbicide. The study recommends the introduction of integrated weed management system to reduce the excessive use of herbicide for weed control. Farmers should be enlightened on the negative effect of excessive use of herbicide on the environment and also the long run impact on climate change. The adoption of high yielding rice varieties such as the Nerica varieties should be promoted in the study area in order to improve the energy productivity in rice production.

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