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Full Length Research Paper

Determination of energy consumption in lowland rice production in Nigeria

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Abstract

Sufficient energy is needed in the right form and at the right time for adequate crop production. One way to optimize energy consumption in agriculture is to determine the efficiency of methods and techniques used. With the current increase in world population, energy consumption needs effective planning. That is why, the input elements need to be identified in order to prescribe the most efficient methods for controlling them. This study was undertaken in order to determine the direct and indirect energy consumption of field operations in a lowland rice production system of Nigeria. All the field parameters were taken in a wet puddling area of 0.25 hectares (25 m x 100 m) laid side by side in a randomized complete block design with three replications. Energy analysis carried out revealed that operational energy consumption for tillage is 41.9 %, planting 31.1 % and Harvesting 21.7 % for the production process and average grain yield was 4,800 kg ha^{-1}.

Keywords: Energy (Indirect and Direct), Tillage, Consumption and Nigeria.

INTRODUCTION

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.

Agricultural productivity cannot hope to increase unless adequate inputs such as power, improved seeds, fertilizers and irrigation water are available in a timely manner and applied judiciously. With the current increase in world population, energy consumption needs effective planning. That is, the input elements need to be identified in order to prescribe the most efficient methods for controlling them. Crop yields and food supplies to consumers are directly linked to energy, which means sufficient energy is needed in the right form at the right time for adequate crop production. One way to optimize energy consumption in agriculture is to determine the efficiency of methods and techniques used (Kitani, 1999; Safa and Tabatabaeefar, 2002). Crop-yield is directly proportional to the energy input (Srivastava, 1982). Fuel and fertilizers (N and P) account for the largest share (>75 %) of all energy expenditures in a mixed cropping system (Hetz, 1992; Ahmad, 1994; Safa and Tabatabaeefar, 2002). Fluck and Baird (1980) hypothesized that the highest partial energy productivity is achieved at the point of minimum mechanization energy inputs and increasing mechanization energy increase crop yield at a decreasing rate. To adequately evaluate crop production energy requirements and be able to choose alternative crop production systems, energy data need to be collected for machinery and soils of major crop production systems.

Field studies need to be conducted in paddy soils to enable the compilation of a more thorough tillage energy database. Field operating energy data is also needed for fertilizer, lime and pesticide applications and for transplanters and harvesters. Energy requirements of various crop production systems can then be determined and compared. This study was therefore undertaken to establish an initial data bank of field operating energy involved in a lowland rice production system of Nigeria.

MATERIALS AND METHOD

Site Description

This study was carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin, research farm which is 370 m above sea level, Longitude $4^0$30’E, Latitude $8^0$26’N under the southern guinea savannah vegetation on a sandy loam and clay loam soils. All the field parameters were taken in a wet puddling area of 0.25 hectares (25 m x 100 m) laid side by side in a randomized complete block design with three replications.

Description of the Machine Used

The power-tiller or walking tractor, as it is sometimes called is a single-axle (two-wheel) tractor. This particular one is of Indian make and the model is VST-SHAKTI 130 DI with 10 kW (13 hp) rated power, diesel engine of 2,400 rpm rated crankshaft speed. The engine is single cylinder horizontal 4 strokes, water cooled and hand-cranking type. The driving wheels are of two types: the pneumatic type for normal traction and the steel or cage wheel for wet puddling.

Computation of Parameters

Energy analysis was performed based on field operations (tillage, planting, fertilizing, spraying and harvesting) as well as on the direct (fuel and human labour) and indirect (machinery, fertilizer, pesticide, and seed) energy sources involved in the production process.

The direct energy use per hectare for each field operation was computed by the following equation (Moerschner and Gerowitt, 2000):

$$ED = h \times AFU \times PEU \times RU \quad (1)$$

where:

ED = Specific direct energy use (fuel) for a field operation, MJ ha^{-1}.

h = Specific working hours per run, h ha-^{1}

AFU = Average fuel use per working hour, L h^{-1}

PEU = Specific energy value per litre of fuel, MJ L^{-1}

RU = Runs, number of applications in the considered field operation.

The energy contribution of machinery for each field operation was determined by the following equation:

$$EID = \frac{TW \times CED}{UL} \times h \times RU \quad (2)$$

EID = Specific indirect energy for machinery use for a field operation, MJ ha^{-1}

TW = Total weight of the specific machine, kg.

CED = Cumulative energy demand for machinery, MJ kg^{-1}

UL = Wear-out life of machinery, h

h = Specific working hours per run, h ha^{-1}

RU = Runs, number of applications in the considered field operation

The indirect energy per unit area for other production inputs such as fertilizer, pesticides and seed was expressed as:

$$EID = RATE \times MATENF \quad (3)$$

where:

EID = indirect energy input, MJ ha^{-1}

RATE = application rate of input, kg ha^{-1}

MATENF = energy factor of material used, MJkg^{-1}

The rate of labour use in the rice production process was determined for each operation. The labour energy input (MJ ha^{-1}) at every stage in the production process was estimated by the following equation:

$$LABEN = \frac{LABOUR \times TIME}{AREA} \times LABENF \quad (4)$$

where:

LABEN = labour energy, MJ ha^{-1}

LABOUR = number of working labourers

TIME = operating time, h

AREA = operating area, ha

LABENF = labour energy factor, MJ h^{-1}

The energy input intensity (e) was determined from the summation of Equations [1]-[4] and, in short, given by the following expression:

$$e = \frac{E}{A} \quad (5)$$

where:
e = energy input intensity, MJ ha^{-1}
E = total energy consumption, MJ
A = the effective production area, ha.
The energy output intensity (e_0) was derived by multiplying the production intensity (s) by the energy coefficient of seed (B_s):

$$e_0 = B_s \times s \quad (6)$$

where:
e_0 = energy output intensity, MJ ha^{-1}
B_s = energy coefficient of seed, MJ kg^{-1}
s = production intensity, kg ha^{-1}

The overall energy ratio (OER) was determined as the ratio of the energy output intensity to the energy input intensity. It is assumed that, if the OER is greater than 1, then the production system is gaining energy, otherwise it is loosing energy.

$$OER = \frac{e_o}{e} \quad (7)$$

where:
OER = overall energy ratio, dimensionless
e_0 = energy output intensity, MJ ha^{-1}
e = energy input intensity, MJ ha^{-1}

Measurement of field condition during tillage operation

The 600 mm tine cultivator was attached to the power tiller and it was used for puddling of the field before the transplanting of the rice was done. Fashola et al. (2007) have a detailed description of the sawah system on farmers' fields. Some of the parameters assessed during the field test included average speed of operation, average wheel slip/travel reduction, average draught of implement and fuel consumption. The soil properties monitored included soil moisture content, bulk density, porosity, penetrometer resistance/cone index and shear strength. The core technique was used in obtaining samples for bulk density measurement, soil penetrometer and shear vane readings were determine *in situ*. Soil samples were obtained at various depths of 7 cm intervals, soil laboratory tests were all performed using standard procedures by Rautaray et al., (1997).

The theoretical field capacity of an implement is the rate of field coverage that would be obtained if the machine were performing its function 100 % of its rated width (Kepner et. al., 1997).

$$\text{Theoretical field capacity (ha h}^{-1}\text{)} = \frac{w \times s}{10} \quad (8)$$

Where s is the speed of operation (km h^{-1}) and w is the actual width of the implement (m).

The theoretical field capacity, effective field capacity, field efficiency of puddling implements were calculated by recording the time consumed for actual work and the time lost for other miscellaneous activities such as turning at head land, adjustment under field operating conditions, etc.

Effective field capacity (ha h^{-1})

$$= \frac{\text{actual area covered}}{\text{time required to cover the area}} \quad (9)$$

Field efficiency (%)

$$= \frac{\text{effective field capacity}}{\text{theoretical field capacity}} \times 100 \quad (10)$$

RESULTS AND DISCUSSION

Operational Energy Consumption Based on Field Operations

The operational energy consumption in the lowland rice production system was computed for the following field operations: tillage, planting, fertilizing, spraying and harvesting. Operational energy refers to the energy used for mechanization, i.e. direct energy (fuel and human labour) and the indirect energy for machinery use. The irrigation energy expenditure was not included in the energy analysis because the pumping of water during the field water management stage was only situational; it is not a common practice among the lowland rice farmers in Nigeria.

As can be observed from Table 1, the average operational energy consumption was highest for tillage (446.88 MJ ha^{-1}) which accounted for about 41.9 % of the total operational energy consumption (1066.28 MJ ha^{-1}), followed by planting (332.02 MJ ha^{-1}, 31.1 %) and harvesting (232.21 MJ ha^{-1}, 21.7 %). Fertilizing and pesticide spraying did not make any significant contributions to the operational energy consumption.

Total Energy Consumption Based On Energy Sources

The average total energy inputs in this cropping seasons add to 6093.75 MJ ha^{-1}. Based on energy sources, fuel was the main contributor of direct energy with 525.40 $MJha^{-1}$ (8.6 %), and fertilizer recording the highest indirect energy consumption of 4847.40 $MJha^{-1}$ (79.5 %), as shown in Table 2. Human labour, spraying, seeds and indirect energy for machinery use had marginal importance, contributing only 0.3 %, 4.3 %, 1.4 % and 5.8 %, respectively to the total energy consumption.

Table 1. Operational Energy Consumption Distributed by Field Operations

Field Operation	Operational Energy Consumption (MJ ha^{-1})			
	Plot			
	I	II	III	Average
Tillage	446.46	447.51	446.66	446.88
Planting	333.22	332.10	330.76	332.02
Fertilizing	33.32	32.70	33.71	33.24
Spraying	21.56	20.63	23.60	21.93
Harvesting	234.40	230.15	232.10	232.21

Table 2. Total Energy Consumption Distributed by Energy Sources.

Energy Source	Total Energy Consumption (MJ ha^{-1})			
	Plot			
	I	II	III	Average
Direct				
Fuel	525.80	573.60	478	525.40
Human	19.60	21.20	20.68	20.49
Indirect				
Machinery	352.86	350.50	354.68	352.68
Seed	83.70	83.70	83.70	83.70
Fertilizer	4847.40	4847.40	4847.40	4847.40
Spraying	266.56	260.20	265.50	264.08

Overall Energy Ratio and Net Energy Gain

The overall energy ratio (OER) was determined as the ratio of output energy to input energy. It is assumed that, if the OER is greater than 1, then the production system is gaining energy, otherwise it is loosing energy. Average grain yield was 4,800 kg ha^{-1}, representing energy output of 80,352 $MJha^{-1}$, that is, 74, 258.25 MJ net energy gain or 12.2 MJ output per MJ input. Energy input per kilogram grain yield was 1.27 $MJkg^{-1}$. The energy output/input ratio of 12.2 (not including irrigation energy input) observed in the present study indicates that the lowland rice farmers in Nigeria earn at least 12 times of what they put into the production process. Duke (1983) reported that the energy output/input ratios for US rice production range from 1.03 to 1.76, compared to 3.6 or higher for developing countries.

Measurement of Field Condition During Tillage Operation

The results of the field performance evaluation from the experimental plots were summarized as seen in table 3. The test of significance difference between the measured parameters as presented in table 4, were not significant for all the parameters consider except for Slippage, which was seen to be significantly higher in plot III with a mean value of about 11.10 % as compare to the mean values of I and II (10.53 % each). For the non significant parameters however, it was concluded that the effect of tillage operations is relatively the same for all the area under study. These imply that the fuel consumption for instance does not differ significantly across the three plots during the experiment.

The summary of the soil physical properties considered during the experiment were presented in Table 5. Moisture content was seen to record higher mean value after operation than before operation, while cone index was as much as eighty times larger before operation than after operation.

Generally, the following was observed;

- Moisture content and porosity was seen to decrease as the soil depth was increase from 0-7cm through 14-21cm.
- Bulk density and cone index increase as the soil depth was increase from 0-7cm through 14-21cm.

This indicates a positive condition for the flow of water and air through the soil profile and minimum resistance to root growth and proliferation. The puddling operation by the power tiller has improved the soil moisture content, reduced shear strength and penetration resistance as proved by Fashola et al. (2007).

Table 3. Descriptive Statistics of Field Operation Result

Parameters	Plot	N	Mean	Std. Deviation	Std. Error
Slippage	I	3	10.5300	.00000	.00000
	II	3	10.5300	.00000	.00000
	III	3	11.1000	.00000	.00000
	Total	9	10.7200	.28500	.09500
Effective field cap.	I	3	.0470	.00830	.00479
	II	3	.0888	.04619	.02667
	III	3	.0551	.01173	.00677
	Total	9	.0636	.03087	.01029
Theoretical field cap.	I	3	.0504	.00951	.00549
	II	3	.0962	.04870	.02812
	III	3	.0708	.00888	.00513
	Total	9	.0725	.03209	.01070
Field efficiency	I	3	93.3733	1.16509	.67266
	II	3	91.9600	1.52588	.88097
	III	3	91.2633	.80749	.46620
	Total	9	92.1989	1.39689	.46563
Fuel cons.(l/ha)	I	3	11.1900	1.97689	1.14136
	II	3	12.9133	.81224	.46895
	III	3	10.5533	6.27730	3.62420
	Total	9	11.5522	3.48011	1.16004
Fuel cons.(l/hr)	I	3	.5370	.18930	.10929
	II	3	1.1220	.50554	.29187
	III	3	.5370	.18930	.10929
	Total	9	.7320	.40911	.13637
Area of land (ha)	I	3	.0351	.00495	.00286
	II	3	.0289	.00656	.00379
	III	3	.0351	.00495	.00286
	Total	9	.0330	.00570	.00190
Average time of operation	I	3	21.7033	3.76513	2.17380
	II	3	13.1533	5.54100	3.19910
	III	3	18.7033	4.53169	2.61637
	Total	9	17.8533	5.51968	1.83989

Table 4. Test of Main Factor Effect (ANOVA)

		Sum of Squares	df	Mean Square	F	Sig.
Slippage	Between Groups	.650	2	0.325	65535.	0.001*.
	Within Groups	.000	6	4.96E-06		
	Total	.650	8			
Effective field cap.	Between Groups	.003	2	.001	1.888	.231ns
	Within Groups	.005	6	.001		
	Total	.008	8			
Theoretical field cap.	Between Groups	.003	2	.002	1.862	.235ns
	Within Groups	.005	6	.001		
	Total	.008	8			
Field efficiency	Between Groups	6.935	2	3.467	2.398	.172ns
	Within Groups	8.676	6	1.446		
	Total	15.610	8			
Fuel cons.(l/ha)	Between Groups	8.945	2	4.472	.305	.748ns
	Within Groups	87.945	6	14.657		
	Total	96.889	8			
Fuel cons.(l/hr)	Between Groups	.684	2	.342	3.137	.117ns
	Within Groups	.654	6	.109		
	Total	1.339	8			
Area of land (ha)	Between Groups	.000	2	.000	1.232	.356ns
	Within Groups	.000	6	.000		
	Total	.000	8			
Average time of operation	Between Groups	112.905	2	56.452	2.589	.155ns
	Within Groups	130.830	6	21.805		
	Total	243.735	8			

*significant at 1% level, ns = not significant

Table 5. Effect of Tillage Tool on Some Soil Physical Properties

Parameter	Activities	N	Mean	Std. Deviation	Std. Error
moisture content	before operation	3	23.6433	9.46724	5.46591
	after operation	3	29.5100	10.07024	5.81405
	Total	6	26.5767	9.31347	3.80221
bulk density	before operation	3	1.5700	.27875	.16093
	after operation	3	1.5200	.15524	.08963
	Total	6	1.5450	.20364	.08314
cone index	before operation	3	51.6800	36.45845	21.04930
	after operation	3	6.2033	7.94620	4.58774
	Total	6	28.9417	34.31301	14.00823
shear strength	before operation	3	.0320	.02458	.01419
	after operation	3	.0053	.00503	.00291
	Total	6	.0187	.02157	.00880
porosity	before operation	3	40.7667	10.54008	6.08532
	after operation	3	42.6667	5.85861	3.38247
	Total	6	41.7167	7.69738	3.14244

CONCLUSIONS

The production energy indicators were evaluated using field data collected during the 2011 main cropping seasons. The indicators included measures of total energy use per unit of effective cropping area (energy intensity) and per unit of rice seed production. For international comparison, a measure of energy conversion efficiency in terms of the overall energy ratio (energy output per unit energy input) was included. Since the goal of the study was to consider total energy inputs as an indicator of sustainability, it was necessary to include the energy requirements to manufacture and transport consumable items such as fertilizer and pesticides as indirect energy inputs. The indirect energy associated with agricultural machinery use was also considered as an important aspect of mechanization. However, the energy inputs associated with the manufacture of capital items such as vehicles for transportation and other farm improvements were not included in the present study. Since different international studies use different indicators, all the results are presented here to aid comparison. Probably, only the limited set described above is required to specify the energy performance of a lowland rice farm.

REFERENCES

Abubakar, MS, Ahmed D (2010). Pattern of energy consumption in Millet production for selected farms in Jigawa, Nigeria. Australian J. Basic and Appl. Sci. 4(4): 665-672.

Ahmad B (1994). Energetics of Major Crops in Mixed Cropping System. AMA, 25(3): 52-54.

Akinbola LA (2002). Technology dissemination, agricultural productivity and poverty reduction in rural sector of Nigeria. Poverty reduction and the Nigerian Agricultural Sector, El-Shadai Global Ventures Ltd. Ibadan. pp: 27 – 35.

Amaza PS, Olayemi JK (2002). Analysis of technical efficiency in food crop production in Gombe State, Nigeria. Applied Economics Letters. 9: 54- 60.

Atala TK, Voh JP (1994). Utilization and sustainability of fadama in northern Nigeria: Input and extension delivery system. Strategies for Sustainable Use of Fadama lands in Northern Nigeria. IIED and CSER, ABU Zaria, Nigeria, p: 147.

Duke, JA (1983). Handbook of Energy Crops. http://ww.hort.purdue.edu/newcrop/duke_energy/Oryza_sativa.html#references. Accessed 12 December 2010.

Fashola O O, Ademiluyi Y S, Faleye T, David J, Wakatsuki T (2007). Machinery systems management of walking tractor (power tiller) for rice production (*sawah*) in Nigeria. *J. Food, Agric. Environ.* (JFAE) (5): 283

Federal Ministry of Agriculture, (1993). In Amaza, PS, Olayemi, JK (2002). Analysis of technical efficiency in food crop production in Gombe State, Nigeria. J. Appl. Econ. Letters. 9: 51 – 54.

Fluck RC, Baird CD (1980). Agricultural Energetics. AVI Publishing Company Inc., West Port, Connecticut.

Hetz EJ (1992). Energy Utilization in Chilean Agriculture. AMA, 23(2): 25-6.

Imolehin ED, Wada AC (2000). Meeting rice production and consumption demand of Nigeria with improved technologies, International Rice Commission Newsletter; Vol. 49, FAO Rome, Pp 33-44

Jones PM (1995). The rice plant and its environment; West African Rice Development Association Training Guide 2. Pp 1 – 6.

Kepner RA, Bainer R, Barger EL (1997) Principles of Farm Machinery, 3rd Ed. CSB Pubilshers and Distributor, Delhi, India. p 45.

Kitani O (1999). CIGR Handbook of Agricultural Engineering, Volume V -Energy and Biomass Engineering. ASAE Publication.

Kolawole A, Scoones I (1994). Fadama land use and sustainability in northern Nigeria: Strategies for the sustainable use of fadama lands in northern Nigeria. CSER/ABU Zaria and IIED. London, p 29.

Moerschner J, Gerowitt B (2000). Direct and indirect energy use in arable farming - An example on winter wheat in Northern Germany. In: Weidema, B.P. and M.J.G Meeusen (Eds.), Agricultural Data for Life Cycle Assessments. The Hague, Agricultural Economics Research Institute (LEI). Report 2.00.01, Volume 1. February p195.

Okuneye PA (2001). Rising cost of food price and food insecurity in Nigeria and its implication for poverty reduction. Central Bank of Nigeria Economic and Financial Review. 39 (14): 88 – 110.

Olayemi JK (1998). Food security in Nigeria. Research Report NO. 2 Development Policy Centre Ibadan, Nigeria, Pp: 1 – 85.

Rautaray SK, Watts CW, Dexter AR (1997). Puddling effects on soil physical properties and wetland rice field Agron. J. 80 (1). 34 – 39.

Safa M, Tabatabaeefar A (2002). Energy Consumption in Wheat Production in Irrigated and Dry Land Farming. In: Proc. Intl. Agric. Engg. Conf., Wuxi, China, Nov. 28-30, 2002.

Srivastava AC (1982). A Comparative Study of Conventional and Mechanized Farming Relative to Energy Use and Cost. AMA. Spring 1982. Pp 42 - 46.

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