ENERGY EFFICIENCY AND GLOBAL WARMING POTENTIAL OF RICE (*Oryza sativa*) PRODUCTION IN LOKOJA, NIGERIA.

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Abstract
Energy use in agriculture has developed in response to population increase, limited supply of arable land and desire for an increasing standard of living. Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural production, since it enhances financial savings, fossil resources preservation and air pollution reduction This study determined energy efficiency and global warming effect of rice production in Lokoja, Kogi state.

Structured questionnaires were administered to selected rice farmers in the study location to collect data on the input and output resources per hectare of rice cultivation. Secondary data which were not site-specific were sourced from relevant literature and database. Basic information on energy inputs and rice yields were entered into Excel spreadsheet SPSS 16.0 for analysis and descriptive statistics as well as graphs were used in the interpretation of the data.

The study indicated that manual energy accounted for 25.49% of total energy used, while thermal and chemical energy were 7.64% and 66.87% respectively. Other energetic parameters obtained include: energy ratio 3.59; energy productivity 0.24 kg/MJ; specific energy 4.09MJ/kg; and Net energy gain 19093.72 MJ/ha. The total global warming potential in rice cultivation was obtained as 375.53 kg CO_2 equivalent. The results of this study have shown that rice cultivation in study location (Lokoja, Kogi state) is energy efficient based on values of energetic parameters obtained. However, the cultivation of crop has contributed negatively to global warming potential.

Keywords: Energy efficiency, Energy ratio, Energy productivity, Rice production, Global warming potential.

1. INTRODUCTION

Rice is the second most important cereal in the world after wheat in terms of production, and it cuts across regional, religious, cultural, national and international boundaries with very high demand (WARDA, 2005). It is a nutritious food, providing about ninety per cent of calories from carbohydrates and as much as thirteen per cent of calories from protein (WARDA, 2005). Rice production is geographically concentrated in Western and Eastern Asia. Asia is the biggest rice producer, accounting for ninety percent of the world's production and consumption of rice (WARDA, 2005). Today, rice is grown and harvested on every continent except Antarctica where conditions make its growth impossible. Nigeria ranks the highest, both as producer and consumer of rice in the West Africa sub-region (WARDA, 2005). African rice production is concentrated in the sub-Saharan and western regions of the continent, because of population density, easy market access, availability of water etc. (Sakurai, 2006).

Agriculture is an energy user and energy supplier in the form of bio-energy (Alam, et al., 2005). Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labour-intensive practices, or both (Shahin, et al., *2008*).

Efficient use of energy resources in agriculture is one of the principal requirements for sustainable agricultural productions; it provides financial savings, fossil resources preservation and air pollution reduction (Singh, 2000).

Energy is one of the most valuable inputs in production agriculture. It is invested in various forms such as mechanical (farm machines), human labour, animal draft, chemical fertilizer (pesticides, herbicides), electrical, etc. The amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production (Stout, 1990).

Energy analysis is necessary for the efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested in every step of the production process (hence identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions (Debendra and Bora, 2008).

Rice production and productivity has been negatively affected all over the world as a result of global warming and climate change. Global warming results from a build up of greenhouse gases in the atmosphere, which allow the sun's rays to enter the atmosphere but prevent the dissipative heat from leaving (Van-Kooten, 1993). Climate change is caused by the release of greenhouse gases into the atmosphere and is expected to affect agriculture and livestock production, hydrologic balances, input supplies and other components of agricultural systems. These gases accumulate in the atmosphere, which result in global warming (Aydinalp and Cresser, 2008). The production of greenhouse gases is enhanced by a variety of human activities including agriculture.

Koc and Ceylan (2013) reported that rice production levels fell because of global climate change and scarcity, thus putting foreign trade relations in dire straits. Due to the fact that rice is cultivated mostly along flood plains, the rise in sea level has caused recurrent floods affecting the rice just after the time of flowering when farmers are expecting their harvest. This effect has also caused the burning off of the flowers and leaves of the plant in some places where drought and early rainfall cessation is being experienced.

Net emissions of CO_2, CH_4, and N_2O can be reduced by undertaking energy efficient management practices like variable rate fertilizing, no-till farming, and more selective use of pesticides. This study is therefore aimed at determining the energy efficiency and global warming potential of rice production in Lokoja, Nigeria. Other practices associated with reduction in energy-use include: the use of shelterbelts, crop diversification and inclusion of pulse crops, legume green manuring, improved fertilizer management practices, precision agriculture and the conversion of marginal cropland to grassland or forest. These practices result in carbon sequestration, one process by which atmospheric carbon is stored in the soil, and will further reduce the effects of global warming (Zentner, 1998).

2. MATERIALS AND METHODS

2.1 Data Collection

Primary data on land area sown with rice, sources of power utilized, number of hours needed in each operation for rice cultivation, and total crop production were collected through a structured questionnaire prepared to capture required information from farmers selected at random in the study area which is along the flood plain of River Niger at Lokoja, Kogi State. The area lies between latitude 7.50^0 N and longitude 6.44^0 E, and is predominantly occupied by Nupe, Kakanda and Bassa tribes. Secondary data were collected from published materials such as journals, proceedings, technical reports, textbooks, etc and the information was used in the calculations.

2.2 Description of Rice Cultivation Operation in the Study Area

Rice planting is done manually. Crop maintenance operation carried out after planting is also done manually. For fertilizer application, 100 kg/ha of NPK is used. Pre-emergence herbicide (2 kg of Oryzo plus and gramoxone) is sprayed on the field immediately after planting or at most two days after planting before the crop begins to germinate at the rate of 2.5 L/ha. Post-emergence herbicide (2 kg of Solito) is also applied after 8 weeks of planting. This serves the purpose of supplemental weeding before the crop begins to flower so that its yield can be enhanced. Bird scaring is an activity that is carried out for three weeks from the 10^{th} week to the 13^{th} week when the stalks begin to mature. This was done by employing people who drive away the birds manually, in order to prevent them from sucking out the milk in the head which otherwise would have become the grain. Harvesting, threshing and packing operations are also carried out manually.

2.3 Computations

The inputs used for rice production in the study area include; manual energy (human labour), seeds, thermal energy (fossil fuel), and chemical energy (fertilizers, herbicides). For the estimation of energy input for agriculture, an average of 8 hours of work per day was selected according to Ozkan, et al.,(2004). All these inputs were converted to energy equivalent using Table 1.

Table 1: Energy Equivalent of Inputs and Outputs in the Production of Rice

Particulars	Unit	Energy Equivalent (MJ/unit)	Reference
A. Inputs			
1. Human labour	h	1.96	Mandal et al., 2002
2. Machinery	kg	62.70	Mandal et al., 2002
3. Diesel and Lubricants	L	56.31	Mandal et al., 2002
4. Tractor	kg	93.61	Canackci et al., 2005
5. Chemical fertilizers	kg		
(a) Nitrogen	(N)	60.60	Mandal et al., 2002
(b) Phosphate	(P_2O_5)	12.00	Mandal et al., 2002
(c) Potassium	(K_2O)	6.70	Mandal et al., 2002
6. Chemicals			
(a) Insecticides	kg	101.20	Yaldiz et al., 1993
(b) Fungicides	kg	216.00	Yadav et al., 2013
(c) Herbicides	kg	238.00	Yadav et al.,2013
7. Seed (Rice)	kg	17.00	Canackci et al., 2005
B. Outputs			
1. Rice Grain	kg	17.00	Mandal et al., 2002
2. Straw	kg	12.50	Mandal et al., 2002

2.4 Energetic Parameters

Energy analyses were performed based on the following field operations; land preparation, planting, crop maintenance (MTCE) (bird scarring, herbicides, and fertilizer application), and also harvesting operations.

i. **Energy Efficiency**

This is also called energy ratio. The energy efficiency is the ratio of the total energy output (MJ/ha) to the total energy input (MJ/ha). It was calculated using the equation of Singh et al., 1997 as ;

$$\text{Energy Eff.} = \frac{\textit{Total}\ \text{Energy Input (MJ/ha)}}{\textit{Total}\ \text{Energy Input (MJ/ha)}} \qquad (1)$$

ii. **Energy Productivity**

This is the ratio of the total grain yield (kg/ha) to the total energy input (MJ/ha). It was calculated using equation of Singh et al., 1997 as;

$$\text{Energy Productivity} = \frac{\textit{Grain Yield}\ (kg/ha)}{\textit{Total}\ \text{Energy Input (MJ/ha)}} \qquad (2)$$

iii. Specific Energy

It is the ratio of the total energy input (MJ/ha) to the grain yield (kg/ha). The specific energy is also the inverse of the energy productivity. It was calculated using equation of Singh et al., 1997 as;

$$\text{Specific Energy} = \frac{\textit{Total}\ \text{Energy Input (MJ/ha)}}{\textit{Grain}\ \text{Yeild (kg/ha)}} \qquad (3)$$

iv **Net Energy**

The net energy is the difference between the total energy output and the total energy input. It was calculated using equation of Mandal et al., 2002 as;

Net Energy = Energy Output (MJ/ha) - Energy Input (MJ/ha) (4)

2.5 Green House Gas Emission

Computation for inventory data sets consist of emissions and energy of the activities associated with rice production in Lokoja per hectare. Emission inventory data were not available in Lokoja; thus, they were calculated as a function of production activities and the emission factors (Table 2 and 3) using the following equations:

Emission = Activity x Emission Factor (5)

Impact = Emission x Classification Factor (6)

TABLE 2: Activity Data for Calculating GHG Emissions in Rice Production Systems

Source	Activity	Emission Value	Unit (per ha)
Land preparation	Diesel use	9.40	kg fuel
Pesticide application	Pesticide use (propanil)	3.87	kg
Fertiliser application	N fertiliser use	37.05	kg
	P fertiliser use	37.05	kg
	K fertiliser use	37.05	kg
Herbicides application	Chemical use (glyphosate)	0.10	kg

Source: Eshun et al., (2013).

Table 3: Classification Factors Used For Emissions of GHG in Rice Production Systems

Compounds	Classification factors	Reference
CO_2	1 kg = 1 CO_2-eq	(IPCC, 1997)
CH_4	1 kg = 21 CO_2-eq	(IPCC, 1997)
N_2O	1 kg = 310 CO_2-eq	(IPCC, 1997)

Source: Eshun et al., (2013).

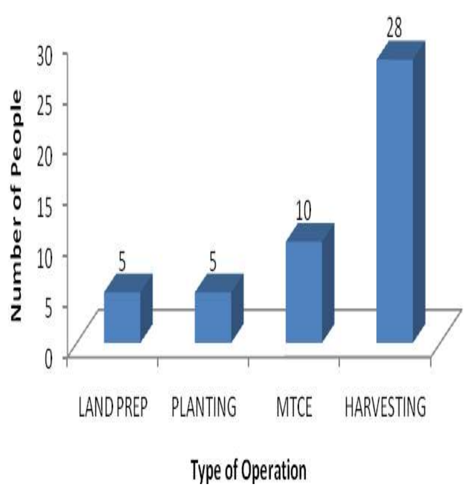
3. RESULTS AND DISCUSSION

3.1 Human Labour Use in Rice Production

The result for the cultivation of one hectare of rice in Lokoja indicated that the level of mechanisation is very low as human labour is mostly used to carry out all the four operations considered. Five (5) people (10.42%) were involved in land preparation and planting respectively; Ten (10) people (20.83%) were involved in crop maintenance and twenty-eight (28) people (58.33%) were involved in harvesting. The values are shown in Figure 1.

3.2 Time Use in Rice Production

The time distribution in the production of rice indicated that out of the total 220 hours of operation, land preparation took 10 hours (4.54%); planting 16 hours (7.27%); crop maintenance 150 hours (68.18%) and harvesting took 44 hours (20.00%) respectively. It was obvious that crop maintenance operation is the highest consumer of time and energy, since energy is a time dependent concept. To reduce the total time taken, there is a need to minimise the time required for bird scaring (126 hours, 57.27%) by available mechanical or biological bird-scaring devices instead of having to engage human beings. This will also help to reduce drudgery associated with the activity. The values are shown in Figure 2.



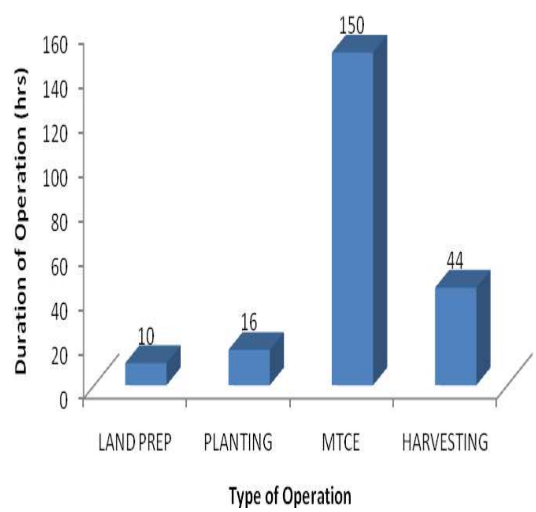


Fig. 1: Human Labour use Fig. 2: Duration per operation in rice production

Note: MTCE represents crop maintenance/ protection operations.

3.3 Diesel and Lubricants Use in Rice Production

The only operation which required the use of diesel in rice production is ploughing. Ten (10) L/ha of diesel was used for ploughing.

3.4 Chemical Use in Rice Production

The use of chemicals in rice production occurs during land preparation (herbicide application) and crop maintenance (application of inorganic fertilizers, both pre-emergence and post-emergence herbicides). Of the total of 106.00 kg of chemicals used for both land preparation and crop maintenance, 2 kg (1.89%) was used for land preparation while 104 kg (98.11 %)

was used for crop maintenance. This is shown in Figure 3. Also, 6 kg (5.66%) herbicides were used while 100 kg (94.34%) inorganic fertilizers were used. This indicates that the bulk of the chemicals used on rice farm are inorganic fertilizers (nitrogen, phosphorus and potassium) which led to the green house gas emissions, and this contributed to climate change and global warming. The values obtained also compares with those obtained by Pervanchon et al.,(2002) and Zentner et al., (2004).

In order to ensure climatic and environmental sustainability, there is a great need to reduce the quantity of emission from these chemical substances, and organic fertilizers could be used to replace or highly supplement the prevailing use of inorganic fertilizers.

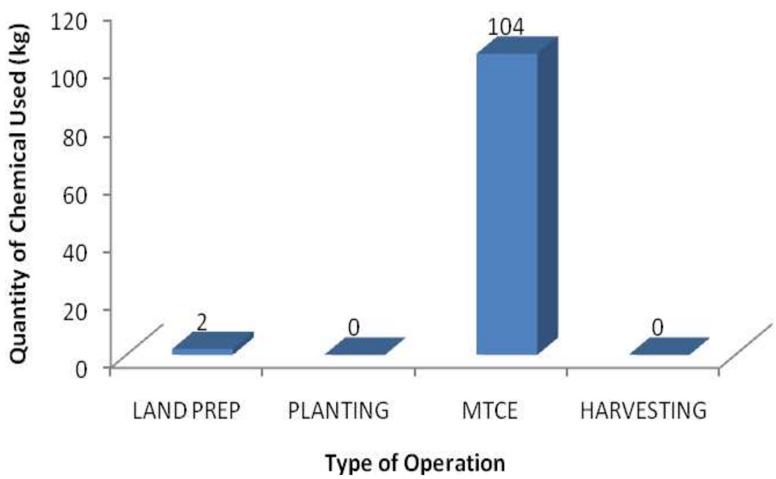


Fig. 3: Chemical use in rice production

Table 4: Inventory of Input Use in Rain fed Rice Production per Hectare in Lokoja

Operation	Manual (M) (people)	Time (T) (hr)	M × T	Diesel (D) (ltrs)	Chemical (C) (kg)
A. Land Preparation					
i. Land Clearing	3	8	24	—	2.00
ii. Ploughing	2	2	4	—	—
iii. Harrowing	—	—	—	—	—
Total	**5**	**10**	**50**	**10**	**2.00**
B. Planting	**5**	**16**	**80**	—	—
C. Crop Maintenance					
i. Fertilizer	2	8	16	—	50.00
a. N	—	—	—	—	25.00
b. P_2O_5	—	—	—	—	25.00
c.K_2O	—	—	—	—	—
ii. Pre-emergence	3	8	24	—	2.00
iii. Post-emergence	2	8	16	—	2.00
iv. Bird Scaring	3	126	378	—	—

Total	**10**	**150**	**1500**	**—**	**104.00**
D. Harvesting					
i. Harvesting	10	16	160	—	—
ii. Threshing	8	12	96	—	—
iii. Packaging	10	16	160	—	—
Total	**28**	**44**	**1232**	**—**	**—**

3.5 Interactive Effect of Human Labour, Time Consumption, Fuel and Chemical Use on Rice Production in Lokoja

The interaction between time and labour use (man hour) revealed that, of the total 2862 man hours involved in the production of one hectare of rice, crop maintenance took 1500 man hours (52.41%), harvesting (1232, 43.04%), planting (80, 2.80%) and land preparation (50, 1.75%) respectively. On the average time used per man, crop maintenance operation required an average of 15 hours/man; Planting 3.2 hours/man, land preparation 2.00 hours/man, and harvesting 1.57 hours/man respectively. This shows that crop maintenance operation was the highest both in the combined man hour and average time consumption per person among all the factors considered. It had an average consumption time of five (5) greater than what was consumed during planting operation. This goes to indicate that so much time is used by human labour in crop maintenance operations especially bird scaring as shown in Figures 4 and 5 respectively.

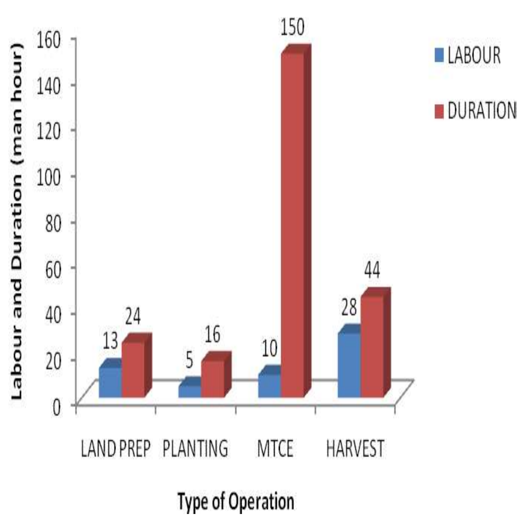


Fig. 4: Interactive of labour and duration (Average duration/man) expended

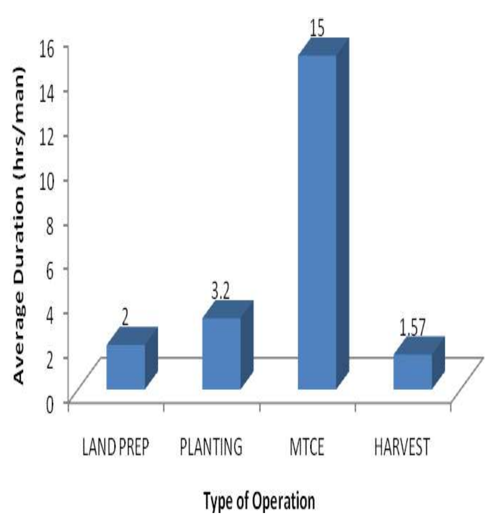


Fig.5: Average time consumption per man expended in rice production

3.6 Energy Analysis in Rice Production

(i) Energy consumption by types in rice production

The data on the energy inputs for rice production were converted to their equivalent energy in MJ. The total energy used was grouped into Manual, Thermal and Chemical energy and is presented in Table 5. Manual energy was used for all the operations involved in rice production, chemical energy was used in land clearing and maintenance operations while thermal energy was used only for land preparation (ploughing).

From Table 5 chemical energy contributed 4925.50 MJ (66.87%) and is the single largest contributor of energy in rice production. This is due to the use of NPK fertilizer and herbicides (for land clearing, pre-emergence and post-emergence). The NPK fertilizer contains nitrogen, phosphorus and potassium and is in the form of N, P_2O_5 and K_2O respectively. The energy contributions of the individual chemicals were also calculated and the results indicated that nitrogen (N) contributed the highest overall individual energy (3030 MJ) which is 57.16% and 41.13% of the chemical energy use and total energy use respectively. This is followed by P_2O_5 (300MJ, 4.07 %) and K_2O (167.50, 2.27%). This high value of energy consumption through fertilizer usage is comparable with other works (Khan, *et.al*, 2010).

Manual energy contributed the second largest share of energy in rice production which is 1877.68 MJ (25.49%) per hectare. Of this value bird scaring contributed 740.88 MJ which is 87.10% of the manual energy used and 10.06% of the total energy consumed. This makes bird-scaring the second largest individual contributor to the overall energy in rice production. The value is followed by harvesting (313.60 MJ, 4.26%), packaging (313.60 MJ, 4.26%), threshing (188.16 MJ, 2.55%), planting (156.8 MJ, 2.13%), land clearing (47.04 MJ, 0.64%), pre-emergence herbicide (47.04 MJ, 0.64%), post-emergence (31.36 MJ, 0.44%), fertilizer application (31.36 MJ, 0.44%) and ploughing 7.84 MJ (0.10%) respectively.

Thermal energy only contributed 563.10 MJ (7.64%) of the total energy and this came from the diesel used during ploughing.

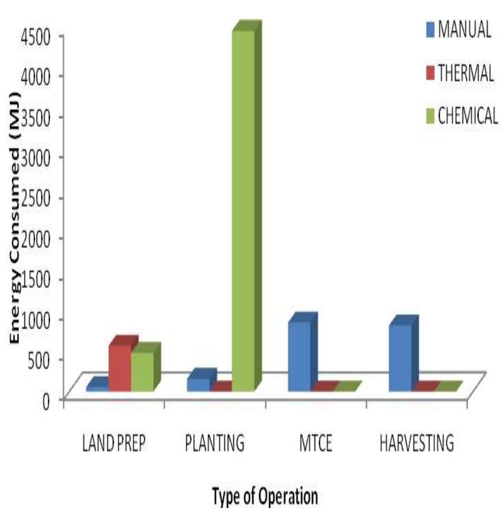
Table 5: Equivalent Energy (MJ) Consumed in Rice Production

Operation	Manual Energy (MJ)	Thermal Energy (MJ)	Chemical Energy (MJ)	Total Energy (MJ)	% of Total
A. Land Preparation					
i. Land Clearing	47.04	—	476.00	523.04	7.10
ii. Ploughing	7.84	563.10	—	570.94	7.75
Total	**54.88**	**563.10**	**476.00**	**1093.98**	**14.85**
B. Planting	**156.80**	**—**	**—**	**156.80**	**2.13**
C. Crop Maintenance					
i. Fertilizer	31.36	—	—	31.36	0.43
a. N	—	—	3030.00	3030.00	41.13
b. P_2O_5	—	—	300.00	300.00	4.07
c.K_2O	—	—	167.50	167.50	2.27

ii. Pre-emergence	47.04	—	476.00	523.04	7.10
iii. Post-emergence	31.36	—	476.00	507.36	6.88
iv. Bird Scaring	740.88	—	—	740.88	10.06
Total	**850.64**	—	**4449.50**	**5300.14**	**71.95**
D. Harvesting					
i. Harvesting	313.60	—	—	313.60	4.26
ii. Threshing	188.16	—	—	188.16	2.55
iii. Packaging	313.60	—	—	313.60	4.26
Total	**815.36**	—	—	**815.36**	**11.06**
Grand Total	**1877.68**	**563.10**	**4925.50**	**7366.28**	**100.00**
% of Total	**25.49**	**7.64**	**66.87**	**100.00**	—

(ii) Energy consumption by operation

The percentage of energy used for each operation was also considered in order to identify the energy consumed by each operation and which operation consumed the highest energy. Figure 7 shows that crop maintenance operation has the highest energy consumption of 5300.14 MJ which represents 71.95% of the total energy used. This is followed by land preparation (1093.98 MJ, 14.85%), harvesting (815.36 MJ, 11.06%) and planting (156.80 MJ, 2.13%) respectively. Thus, effort should be made to reduce the energy consumption during crop maintenance operation. Other environmental-friendly methods of improving soil fertility such as use of animal dung and plant residues should be employed to replace or supplement the use of synthetic nitrogenous fertilizer.



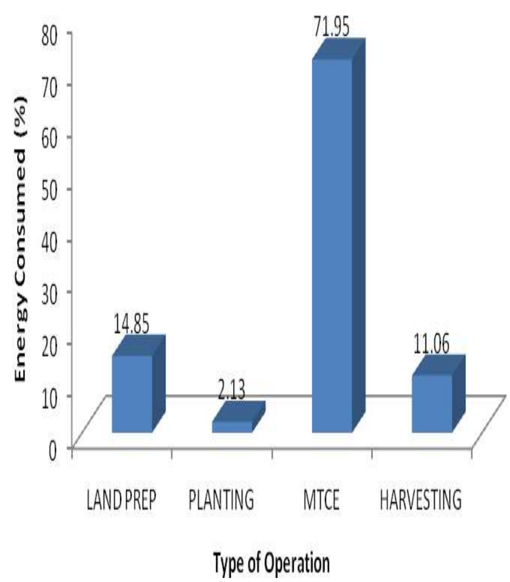


Fig. 6: Interaction of energy and operation type in rice production

Fig. 7: % Total energy used by operation in rice production

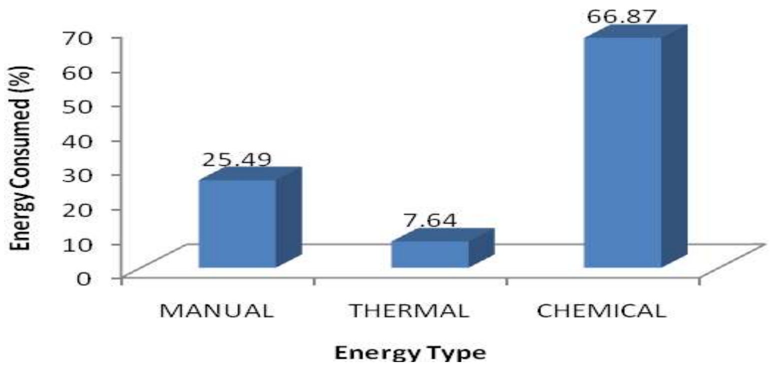


Figure 8: Percentage total energy type used in rice production in Lokoja

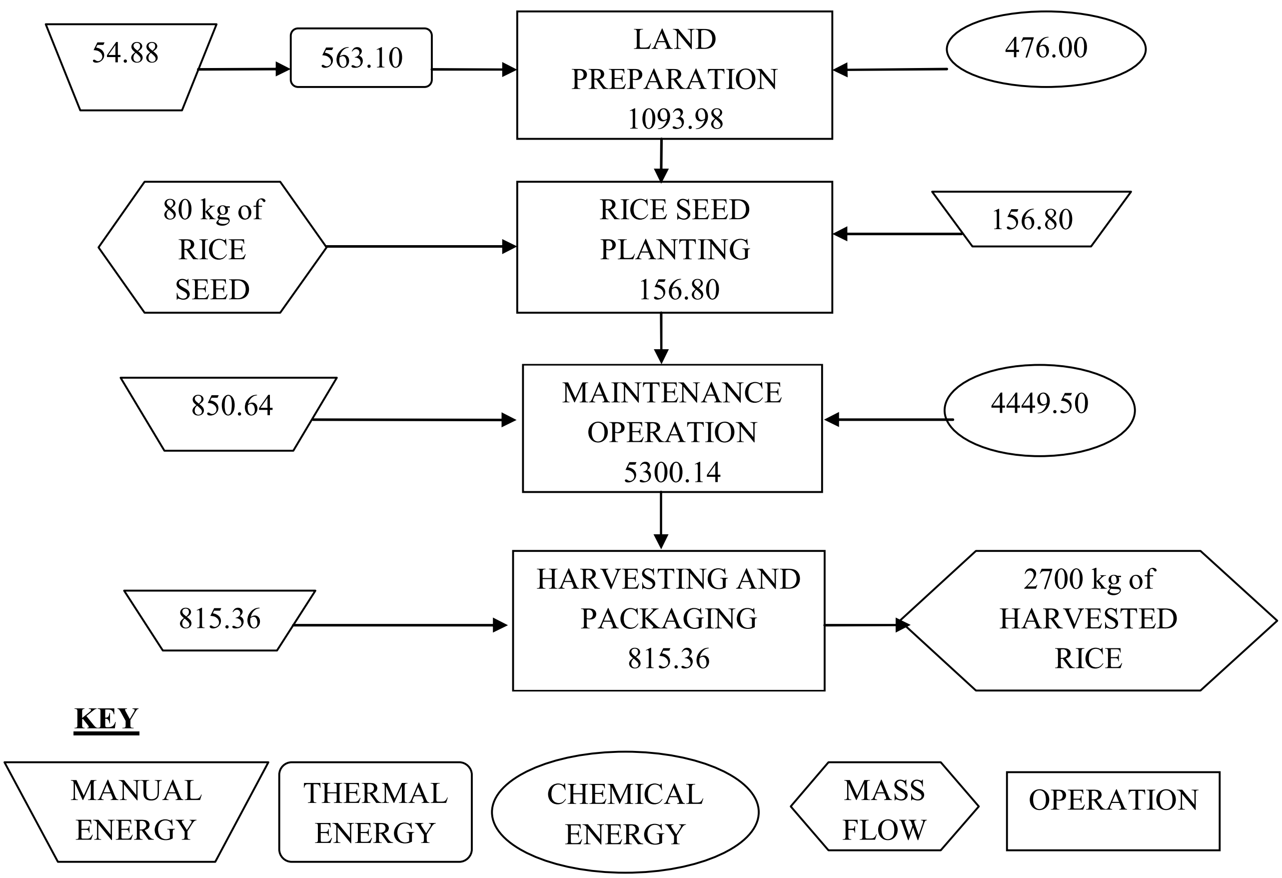


Figure 9: Energy accounting and mass flow diagram for rice production in Lokoja

(iii) Other energetic parameters considered in the study

Table 6 gives a summary of different energetic parameters considered in Rice production in Lokoja. Energy ratio value was 3.59. This compares well with 3.13 obtained by Shahin et al., (2008) who worked on wheat in Iran but is lower than that obtained by Khan *et al,* (2010) who had a value of 6.70 in Australia. Avval et al., (2012) got a value of 4.24 for sunflower production in Iran. The higher values obtained in Australia and Iran was due to the higher level of mechanization involved in their production system.

The value of energy productivity was 0.244 kg/MJ which compares well with Shahin et al., (2008) and Avval et al (2012) who had 0.16 kg/MJ and 0.17 kg/MJ respectively. However, Khan et al (2010) obtained 1.48 kg/MJ while Avval et al obtained 0.17 kg/MJ. Energy productivity measures the amount of a product obtained per unit of energy input. It evaluates how efficiently energy is utilized in different production systems that yield a particular product Ortiz-canavate and Hermanz, (1999).

Specific energy was 4.092MJ/kg which compares favourably with Shahin et al., (2008) and Avval et al (2012) who obtained 6.25MJ/kg and 5.90 MJ/kg respectively. The higher the value the more profitable is the production process in terms of time, cost and energy relationship.

The net energy gain (NEG) was 19093.72 MJ/ha. It is the difference between the total energy output and total energy input and it compares with Avval et al., (2012) who obtained 31062.7 MJ/ha. This value revealed that the crop is energetically sound as it produced large energy gain.

TABLE 6: Summary of values of energetic parameters considered for rice production in Lokoja.

ITEM	UNIT	QUANTITY
Energy Ratio/Efficiency	-	3.59
Energy Productivity	kg/MJ	0.244
Specific Energy	MJ/kg	4.092
Net Energy Gain (NEG)	MJ	19093.72

3.7 Green house gases emission and global warming potential

Carbon (IV) oxide emitted was 126.3 kg CO_2 equiv (26.5%); methane 5.72 kg CO_2 equiv (1.2%) and nitrogen (II) oxide 345.183 kg CO_2 equiv (72.3%) respectively from one hectare of rice produced in Lokoja as shown in Table 7 and Figure 10.

Furthermore, Land preparation accounted for 30.89 kg (7%)-CO_2 equivalent; Planting 21.48kg (5%); Fertiliser 345 kg (72%) and Transport 50.82 kg (10%) of the total green house gases emitted respectively.

The total impact of green house gases from one hectare of rice cultivated is 1,042.42 kg of which N2O accounted for 1011.46 kg (97.03 %); CO2 29.61 KG (2.84%) and CH4 1.36 kg (0.13 %) respectively as presented in Table 8. These gaseous emissions indicated that rice production has greatly contributed to global warming potential in the study area (Lokoja).

TABLE 7: Greenhouse gases emission from rice production activities (kgCO_2eq/ha)

Activity/Source	CO_2 Emission		CH_4 Emission		N_2O Emission		Total	
	kg	kg CO_2 equiv	kg	kg CO_2 equiv	kg	kg CO_2 equiv	kg CO_2 equiv	%
LAND PREP	29.6	29.6	0.06	1.26	0.0001	0.031	30.89	7
PLANTING	20.5	20.5	0.045	0.95	0.0001	0.031	21.48	5
FERTILISER					1.1	345	345	72
TRANSPORT	48.5	48.5	0.106	2.23	0.0003	0.09	50.82	10
TOTAL	**126.3**	**126.3**	**0.272**	**5.72**	**1.1006**	**345.183**	**477.2**	**100**
% Total		**26.5**		**1.20**		**72.30**		

TABLE 8: Emission and impact of greenhouse gases in rice production in Lokoja

Compounds	E.F ($\times 10^{-3}$)	E	QUANTITY C.F	Impact (kg)	% Total
CO_2	3150.00	9.40	1 kg = 1CO_2-eq	29.61	2.84
CH_4	6.91	9.40	1 kg = 21CO_2-eq	1.36	0.13
N_2O	30.00	37.05	1 kg =310CO_2-eq	1011.46	97.03
Total				**1042.43**	

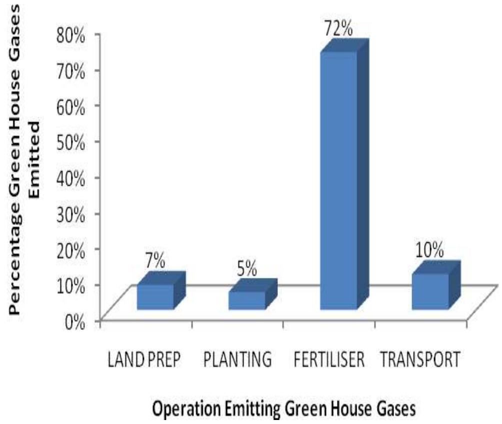


Fig. 10: Activity emitting green house gases

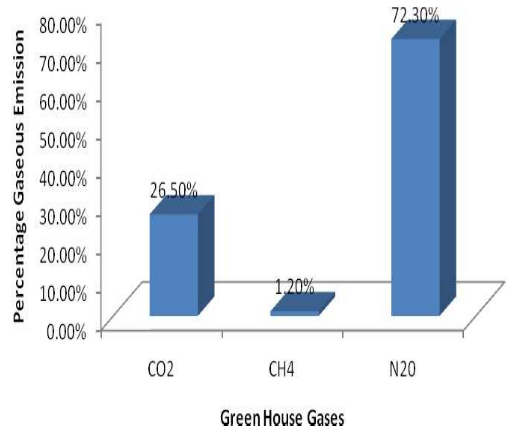


Fig. 11: Percentage gaseous emission from major green house gases

4. CONCLUSIONS

The result of this work revealed that human labour was involved in the execution of all operations carried out in rice production in Lokoja, particular for such operations such as; weeding, harvesting, land preparation which led to drudgery and loss of many man-hours. Fertilizer application is the major consumer of energy and also the highest contributor of green house gases emission in rice production. It consumed a total of 4449.50 MJ of chemical energy and emitted 345 kg CO2 equiv, which indicated a high potential of global warming impact from rice production in Lokoja, Nigeria.

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