Profitability and energy gaps of semi-mechanised and traditional rice production technologies in north central and north western Nigeria

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Abstract: Efficient use of energies on crop production helps to achieve increased production and productivity as well as profitability and competitiveness of agricultural sustainability of rural communities. The study examined profitability and energy used of rice production under two different technologies in two States of Nigeria. Primary data through structured questionnaire and interview were administered to 265 rice farmers comprising 57 semi-mechanized (Group 1) and 208 traditional (Group 2) rice farmers in both States. Results revealed that the semi-mechanized had higher income ₦370,998.2 ($2348.1) per ha compared to ₦307,031.1 ($1943.2) per ha from traditional technology. Group 1 farmers produced a total energy output of 3730.8 kg ha^{-1} compared to Group 2 farmers with energy output of 3170.2 kg ha^{-1}. Conversely, the energy use efficiency, energy productivity and net energy of traditional system indicated high energy use efficiency compared to that of semi-mechanized system. Findings also showed that non-renewable energy in semi-mechanized (72.1%) was high compared to that of traditional group (32.8%). This could be a result of high usage of chemical fertilizer, herbicide, diesel and machinery. The result also revealed that rice production was driven by indirect energy in Group 1 (58%) and largely by direct energy in Group 2 (64.2%). The study suggests that farmers should imbibe machinery for pre-planting operations and introduce integrated weed management system and farm yard manure to control weed and improve crop nutrient and to reduce cost of production.

Keywords: rice, net energy, efficiency, net margin

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1 Introduction

Rice (*Oryza sativa* L.) belongs to the Gramineae family, which is the most important of all cultivated crops world-wide (Oladimeji et al., 2013b). Rice production started in Nigeria in 1500 BC with low-yielding indigenous red grain species *Oryza glaberrima* that was widely grown in the Niger Delta area (Hardcastle, 1959). Rice is cultivated in virtually all the agro-ecological zones in Nigeria. Despite this, the area apportioned for rice farming still appears small as observed by Oladimeji and Ajao (2014). Further, the shortfall in the supply of rice in Nigeria has been attributed to inefficiency in the use of resources, disincentives from macro-economic environment, continuous rise in per capita consumption brought about by increased population and rapid urbanization and partly to production in the hand of small-scale farmers who use traditional technology (Oladimeji and Abdulsalam, 2014; Oladimeji and Ajao, 2014). For the purpose of this study, a farm that used scientific chemicals (e.g. fertilizer, herbicide, insecticide) and farm machinery such as tractor, planter, combine harvester, sprayer in most of the farm operations was considered semi-mechanised. However, a farm that uses simple farm tools like hoes, cutlasses was considered as

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traditional technology or non-mechanised.

In Nigeria and more commonly in most developing countries, the demand for food products has outstripped supply creating a huge deficit. Although importation of food products was used partially to fill the growing deficits in the past, and presently, its continuation constitutes avoidable drain on the country's scarce foreign earnings, especially during this period of economic recession and dwindling oil prices (Oladimeji et al., 2013a). It suffices to note that Nigeria is the leading consumer and the largest producers of rice in Africa and simultaneously one of the largest rice importers in the world. Available records from FAO (2010) reported in Oladimeji et al. (2013a) revealed that the total domestic rice production in Nigeria for 2 decades period (1990-2008) averaged about 3.2 million tons per annum and ranged from 2.5 million tons in 1990 to 4.2 million tons in 2008 with a standard deviation of 429, 600 tons during the 1990 to 2008 decades. But the estimated demand for rice consumption ranged from 3.8 million tons to 14.5 million tons during the same decades with annual average of approximately 8.0 million tons and standard deviation of 3.3 million tons (Figure 1).

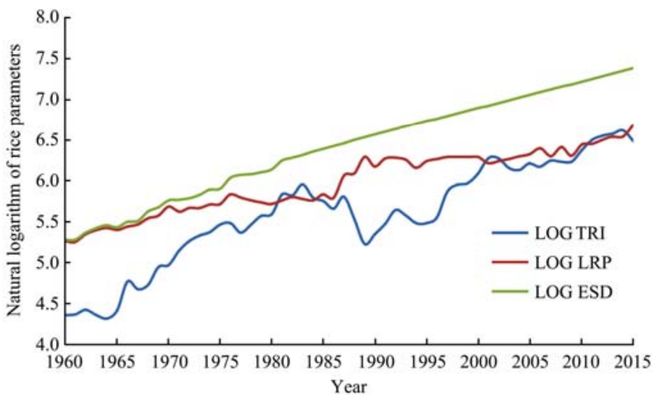

Figure 1 Trend analyses in Local Rice Production (LRP), Total Rice Imported (TRI) and Estimated Demand (ESD) in rice production in Nigeria (1960 - 2015)

Note: computation and graph by author, from the data of Central Bank of Nigeria and National Population Census Records.

Furthermore, the country's self-sufficiency ratio in rice production ranged from 23.6% in 2007 to 79.5% in 1991 with an annual average of 45.6% and standard deviation of 16 (Figure 2). The increase in output of rice over the years was a result of the increase in hectares cultivated. However, there has been falling yield per hectare of rice in Nigeria from 2,069.54 kg per hectare in 1990 to 1,299.8 kg per hectare in 2007 (FAO, 2010). According to the same FAO (2010), the falling yield of rice led to supply deficit situation in the country as well as yield efficiency which fall from 69.0% in 1990 to 43.3% in 2007 with a mean average of about 53% and standard deviation of 8.1.

Figure 2 Trend in self-sufficiency in rice production in Nigeria (1960-2015) (Oladimeji, 2017)

Ozkan et al. (2004) opined that energy is used in agricultural production in direct and indirect ways. Efficient use of these energies on crop production help to achieve increased production and productivity and help the economy, profitability and competitiveness of agricultural sustainability of rural communities (Singh et al., 2002; Namadri, 2011). Energy analysing can be used as a first step towards identifying crop production process that benefit most from increased efficiency (Mohammadi et al., 2008).

Therefore, it becomes imperative to examine energy use in two different technologies that could enhance both small and large scale farmers to be more efficient in the use of available resources which is a major pivot for a profitable farm enterprise at microeconomic level and increased self-sufficiency and export at macro-level. Further, the subject of energy analysis of rice production in Nigeria has received substantial attention in the literature; however, fewer of such studies had estimated energy use and efficiency in rice production. The objectives of this study were to examine profitability and estimate energy use production for two groups of rice farmers with different level of production technology and machinery ownership status in Kebbi and Kwara States, Nigeria.

2 Methodology

2.1 The study area

Nigeria lies between Longitudes 2°49'E and 14°37'E and Latitudes 4°16'N and 13°52' North of the Equator. The climate is tropical, characterized by high temperature and humidity as well as marked wet and dry seasons, though there are variations between South and North. It has a total land area of 923,768.6 km^2 and 139 million people in 2006 (NPC, 2006) with average population and agricultural densities of 150 person km^{-2} and about 3.3 farm families km^{-2} respectively. The latest United Nation estimate at growth rate of 2.48% put the country at about 190 million people with average human density of 204 person km^{-2}. The study was conducted in North-central and North- western Nigeria 40°00'N and 75°09'W. The two region falls within the tropical Guinea and derived savannah zone of Nigeria which combined to form woodland and tall grass savanna (Figure 3).

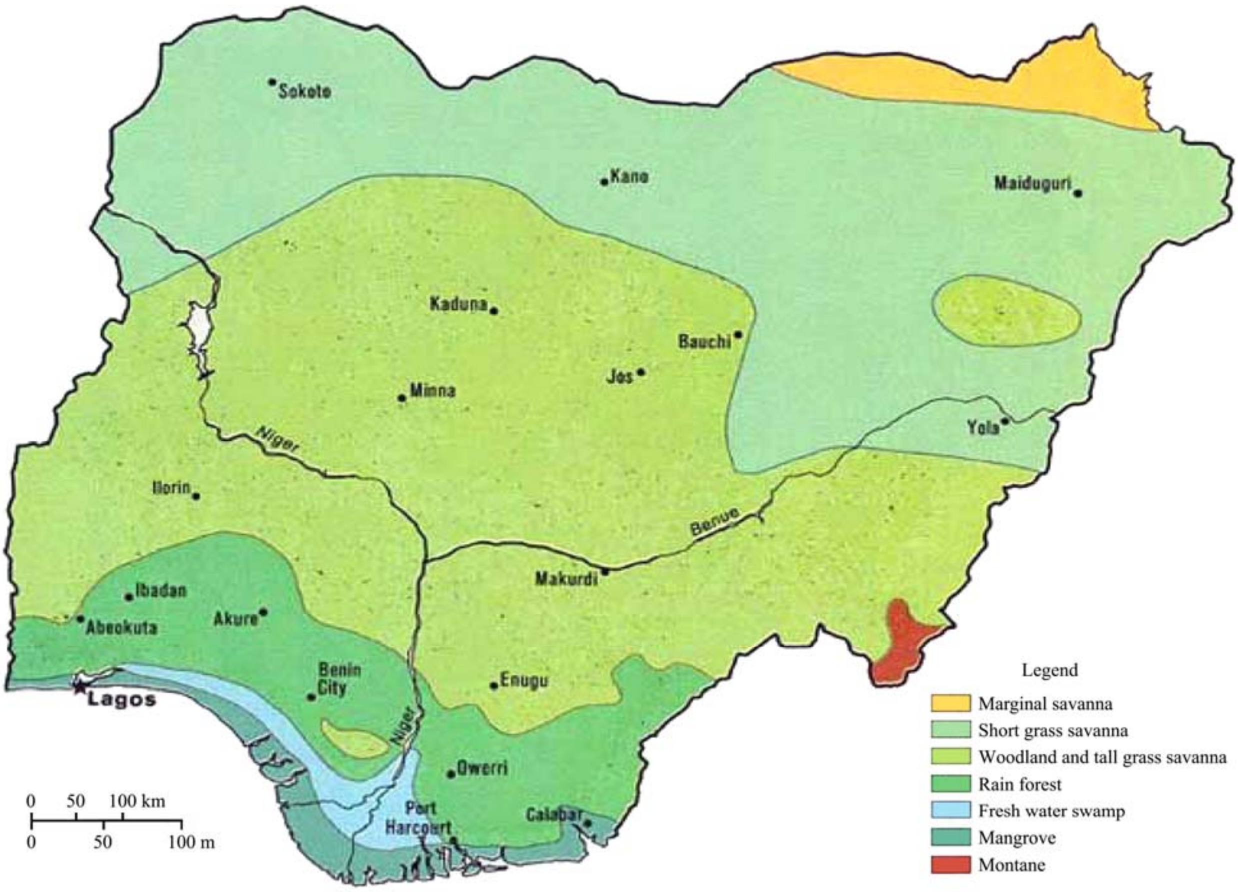

Figure 3 Nigerian vegetation types showing the woodland savanna (study area) (NPC, 2006)

The mean annual rainfall and temperature ranges from 787 mm to 1500 mm and 29.5°C-35°C respectively. Both Kebbi and Kwara States have abundant surface water resources in the form of rivers, such as the Niger, Rima and Ka for irrigation, domestic use, fish and bee farming. The two States belongs to the southern and northern guinea savanna zones characterized by woodland and tall grass (Keay, 1953). The derived savanna zone extends southwards from the southern guinea zone to the forest zone (Adegbola and Onayinka, 1976). The two States were purposefully chosen as the study area for these remarkable factors.

2.2 Data collection and sampling procedure

The study was based on primary sources of the data gathered by field surveys on rice farms in 2013/2014 farming season through questionnaire and interview. A multi-stage random sampling procedure was employed for selecting the representative of rice farmers in Nigeria.

The first stage involved the random selection of 2 States: Kwara and Kebbi States from the list of the 14 States in the two regions including Abuja Federal Capital Territory. The rice producing form local government areas (LGAs) in each State was purposively selected being areas dominated by rice production and, where most of the small rice holders and nearly all mechanised farms were located. The second stage involved the random selection of rice farming villages from LGAs. Finally, with combined efforts of Agricultural Development Project staff, State Ministry of Agriculture, Rice Farming Associations and village heads, a stratified random sampling result in 265 rice farmers comprising 208 traditional and 57 mechanised rice farmers in both States.

It is pertinent to note that the sample size from the two States (Kwara and Kebbi) was determined by adopting Ozkan et al. (2004) and Namdari (2011) method of sample determination given as:

$$n=\frac{\sum N_{cw}S_d}{N_{cw}D^2+\sum N_{cw}S_d^2} \quad (1)$$

where, n is the required sample size (farmers); N is the sample frame (number of farmers in target population); N_{cw} is the number of the population of rice farmers in the North-central and North-western Nigeria; S_d is the standard deviation in the two zones (North Central and North West Nigeria); S^2_d is the variance of in the two zones; d is the precision level, z is the reliability coefficient (1.96 which represents the 95% reliability); $D^2 = d^2/z^2$.

Classification of rice farmers was based on level of farming technology. Semi-mechanised technology consist of farmers who owned or rented machinery such as tractor and imbibed modern management practices such as chemical fertilizers, herbicides, hybrid seeds, knapsack sprayers, irrigation equipment and received extension services. Traditional technology farmers were made up of rice farmers who used solely crude implements such as hoes and cutlasses hence which referred to as non-owners of machinery or imbibed low level of farming technology (Zangeneh et al., 2010; Namdari, 2011), seldom receive extension contacts and low level of hybrid input usage.

The energy input output analysis used standard energy conversion of previous studies cited by Zangeneh et al. (2010), Namdari (2011), Banaeian and Namdari (2011) that obtained energy equivalences of unit inputs (Mega Joule) by multiplying inputs with the coefficients of energy equivalent. Table 1 showed standard energy equivalents that were used for estimated input and output energies in rice production.

The energy use efficiency, the energy productivity, the specific energy and net energy gain were calculated based on the energy equivalents in Table 1 as follows:

$$\text{Energy use efficiency}=\frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (2)$$

$$\text{Energy productivity}=\frac{\text{Rice output (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (3)$$

$$\text{Specific energy}=\frac{\text{Energy input (MJ ha}^{-1})}{\text{Rice yield (kg ha}^{-1})} \quad (4)$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}) - \text{Energy input (MJ ha}^{-1}) \quad (5)$$

Table 1 Standard energy equivalents used for estimated inputs and output in rice production

Variables	Unit	Energy equivalent (MJ)	References
1. Inputs			
i Human labour	h	1.96	Cankci et al., 2005; Yilmax et al., 2005
ii Machinery	h	62.7	Cankci et al., 2005; Yilmax et al., 2005
iii Diesel fuel	L	56.31	Mohammadi et al., 2008; Zangeneh et al., 2010
iv Nitrogen fertilizer	kg	66.14	Alam et al., 2005; Mohammadi et al., 2008
v Farm yard manure	kg	0.30	Cankci et al., 2005; Demiran et al., 2006
vi Chemicals	L	120.0	Mohammadi et al., 2008;
vii H_2O for irrigation	M^3	1.02	Mohammadi et al., 2008
viii Rice seed inputs	kg	14.7	Singh, 2002;
2. Rice output	kg	14.7	Cankci et al., 2005

Note: Adapted from Zangeneh et al. (2010), Namdari, (2011), Banaeian and Namdari, (2011).

For the purpose of this study, net farm income (NFI) per ha and gross margin (GM) per ha were employed to investigate economic analysis of rice production under semi-mechanised and traditional technology respectively. The two models were presented mathematically as:

$$\text{NFI}=\text{GFI}-\text{TVC}-\text{TFC} \quad (6)$$

$$\text{GM}=\text{GFI}-\text{TVC} \quad (7)$$

where: NFI = net farm income (₦ ha^{-1}); GFI = gross farm income (₦ ha^{-1}) = yield (kg ha^{-1}) × sale price (₦ kg^{-1}); TVC = total variable cost (₦ ha^{-1}) and TFC = total fixed cost (₦ ha^{-1}).

Profitability ratios such as the profit margin (PM), gross ratio (GR) and rate of return on investment (ROI) were also computed as:

$$PM\,(\%)=\frac{\text{net margin}}{\text{gross income}}\times 100 \quad (8)$$

$$GR(\%) = \frac{\text{total cost}}{\text{gross return}} \times 100 \quad (9)$$

$$ROI(\%) = \frac{\text{gross income}}{\text{total cost}} \quad (10)$$

Depreciation values were estimated using a straight-line method under the assumption that tractors and irrigation equipment were used for a period of 10 and 5 years respectively before being scrapped without salvage values.

3 Results and discussion

3.1 Cost structure in rice production technologies

Figure 4 depicted cost components used in the two rice production technologies. Result revealed that total variable cost constituted about \$1,145.9 (80%) and \$1,235.4 (97%) of total cost (TC) per hectare of rice production in semi-mechanised and traditional technologies respectively.

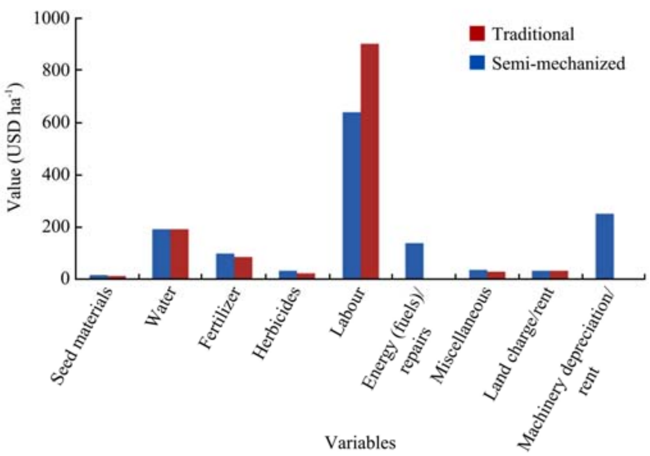

Figure 4 Distribution of total cost (USD ha^{-1}) components of rice production

Note: USD denote United State dollar; ₦158= 1.

Labour cost accounted for about \$638.6 (45%) of TC in semi-mechanised and \$901.6 (71%) of traditional technology. Hence rice production under Group 2 farmers was largely labour intensive which is consistence with a priori expectation that most traditional farmers performed pre and post planting operation with crude implement. The findings of cost component are also in line with studies of Oladimeji et al. (2016) on egusi melon production where labour in semi-mechanised and traditional gulped 47.7% and 67% of TC respectively. The findings also explicitly showed that Group 1 farmers adopt more improved technology such as fertilizer, herbicides and machinery compared to their counterpart.

3.2 Benefit-cost analysis in rice production technologies

Table 2 showed averages costs and returns per hectare of rice production under semi-mechanised and traditional technologies in Nigeria. We shall concentrate on returns accruing to both farmers under the two different technologies and briefly enumerate the multiplier effect of adopting semi-mechanised technology. The net margin method showed that rice production was profitable in the two production technologies. Although the total expenditure for semi-mechanised system amounted to ₦225,929.8 (\$1429.9) per ha while the traditional system was ₦200,200.9 (\$1267.1). Despite this, results revealed that semi-mechnised farmers realized more yield (3730.8 kg ha^{-1}) and invariably higher income, ₦370,998.2 (\$2348.1) per ha compared to yield of 3170.2 kg ha^{-1} and profit of ₦307,031.1 (\$1943.2) per ha from traditional technology. Therefore, the net return analysis revealed that semi-mechanised system had a better leverage to increase rice production to attain rice self-sufficiency production in Nigeria.

Table 2 Details average costs and returns per ha of rice production under two different technologies in Nigeria

Variables	Semi-mechanised system			Traditional system		
	₦ ha^{-1}	USD ha^{-1}	%	₦ ha^{-1}	USD ha^{-1}	%
Revenue from (₦):						
Rice (kg ha^{-1}) = ₦ 160 kg^{-1}	3730.8			3170.2		
A. Gross return	**596928**	**3778.1**		**507232**	**3210.3**	
Variable cost (₦)						
Seed materials	2570.4	16.3	1.4	1650.5	10.4	0.9
Water	30000.0	189.9	16.6	30000.0	189.9	15.4
Fertilizer	15458.7	97.8	8.6	13250.8	83.9	6.8
Herbicides	5205.2	32.9	2.9	3340.7	21.1	1.7
Labour	100904.5	638.6	55.7	142455.3	901.6	73.0
Energy (fuels)/repairs	21600.2	136.7	11.9	-	-	-
Miscellaneous	5320.4	33.7	2.9	4503.6	28.5	2.3
B. Total variable cost	**181059.4**	**1145.9**	**100.0**	**195200.9**	**1235.4**	**100.0**
Fixed cost items						
Land charge/rent	5000.0	31.6	11.1	5000.0	31.6	100
Machinery depreciation/ rent	39870.4	252.3	88.9	-	-	-
C. Total fixed cost	**44870.4**	**284.0**	**100.0**	**5000.0**	**31.6**	**100**
D. Total costs (B+D)	**225929.8**	**1429.9**		**200200.9**	**1267.0**	
E.Net margin per ha (A-D)	370998.2	2348.1		307031.1	1943.2	
Profit margin (E/A)	0.62			0.61		
Gross ratio (D/A)	0.38			0.39		
ROI (A/E)	1.60			1.65		

Source: Field survey, 2013/2014; Note: ₦158= USD1 & United State dollar = \$.

It sufficed to note that traditional rice production technology largely have limitations towards achieving self-sufficiency in rice production viz. drudgery nature, limited size holdings, time consuming and more labour fatigue which results in low yields. Several studies (Ahmadu and Erahabor, 2012; Oladimeji and Ajao, 2014) adjudged that the bulk of rice production in Nigeria lied with small scale farmers with average size holding of 2.0-5.0 ha. Therefore, government policy must promote gradual technology shift to semi-mechanized farming and in the long run total mechanized, to achieve self-sufficiency in rice production. This result agreed with the finding of Cherati et al. (2011), Oladimeji and Abdulsalam (2014), Oladimeji et al. (2016) that reported significant net margin difference between mechanised and traditional technologies in rice production in Iran and vegetable and melon production respectively in Nigeria.

3.3 Level of inputs and outputs usage in rice production technologies

Profitability ratios also in Table 2 indicated that semi-mechanised farming had a better profit margin and gross ratio of 0.62 and 0.38 compared to 0.61 and 0.39 respectively in traditional system. Although the estimated profit margin and gross ratio of the two farming systems had a slight difference. However, the gap between the net margin (profit) of semi-mechanised (₦370998.2) and traditional method (₦307031.1) which amount to ₦62967.1 showed that the difference is very important. This explained that semi-mechanized farming had a better profit margin and gross ratio than the traditional system. The gross ratio is an indicator of the ability of rice farmers to control cost of operation. A less than one ratio is desirable for any farm business. The lower the ratio for semi-mechanised farming (0.38) in this study, the higher the return per Naira invested. A rising ratio showed that variable costs are increasing or that revenue is declining due to falling rice output prices. The gross ratio in two rice production technologies was less than 1. According to Gittinger (1982), enterprises with very high gross ratios in the neighborhood of 90% had difficulty in making adequate returns on investment, due to triple effects of high operating expenses, dwindling rice output, and falling prices; while an abysmally low ratio, say 50%, implied that some costs may have been omitted or grossly underestimated. The return on investment means that for everyone naira invested by rice farmer, a profit of either ₦1.60 or ₦1.65 is made in semi-mechanized or traditional system.

The results of inputs and outputs in rice production technologies per ha were presented in Table 3. Result revealed that semi-mechanised farmers required 528.7 h ha^{-1} of human labour while traditional system used 874.0 h ha^{-1} of the same power. The result implies that semi-mechanised system save 345.3 h ha^{-1} per hectare compared to in traditional system. The finding is consistence with the observation of Namdari (2011) and Oladimeji et al. (2016) that a significant human labour

Table 3 Inputs and outputs in rice production technologies

Inputs/outputs (unit)	Quantity per unit area (ha)			
	Semi-mechanised		Traditional	
	Qty/unit (%)	Grand (%)	Qty/unit (%)	Grand (%)
1. Inputs				
Human labour (h ha^{-1})				
Pre planting operations	50.5 (9.6)	7.0	178.2 (20.4)	19.8
Pre-nursery and nursery	58.8 (11.1)	8.1	75.3 (8.6)	8.4
Seedling (transplanting)	43.4 (8.2)	6.0	45.9 (5.3)	5.1
Watering	143.0 (27.0)	19.7	114.6 (13.1)	12.7
Chemical fertilizer application	43.5 (8.2)	6.0	39.5 (4.5)	4.4
Farm yard manure	10.3 (2.0)	1.4	27.0 (3.1)	3.0
Manual weeding	45.7 (8.6)	6.3	237.2 (27.1)	26.4
herbicides spraying	54.8 (10.4)	7.6	21.9 (2.5)	2.4
Harvesting, threshing & transp.	78.7 (14.9)	10.8	134.4 (15.4)	14.9
Total	528.7 (100)	72.9	874.0 (100)	97.1
Machinery (h ha^{-1})				
Pre planting operations	47.9 (24.3)	6.6	11.5(43.7)	1.3
Herbicides	42.3 (21.5)	5.8	14.8(56.3)	1.6
Fertilizer application	17.4 (8.8)	2.4	-	-
Harvesting, threshing & transp.	89.5 (45.4)	12.3	-	-
Total	197.1(100)	27.1	26.3(100)	2.9
Grand total (L ha^{-1})	725.8	100	900.3	
Diesel fuel (L ha^{-1})				
Land preparation	78 (63.4)		-	
Harvesting, threshing & transp.	45 (36.6)		-	
Total	123(100)		-	
Inputs				
Seed materials (kg ha^{-1})	35.7		48.9	
N_2 Chemical fertilizer (kg ha^{-1})	185.2		87.2	
Farm yard manure (kg ha^{-1})	2590.0		10900.3	
Herbicide chemical (L ha^{-1})	7.4		2.9	
Water (m^3 ha^{-1})	10,000.00		10,000.00	
2. Output				
Rice yield (kg ha^{-1})	3730.8		3170.2	

Source: Field survey, 2013/2014; N_2 denote Nitrogen.

differs between traditional and semi-mechanized technology in watermelon and egusi melon production respectively. However, human labour constituted 72.8% of total hours expended for all operations per ha in semi-mechanised and machinery consumed 27.2%. In traditional technology, human labour accounted for nearly total farm operations (about 97%) and machinery power took a paltry of about 3%. Result further revealed that Group 1 needed a total of 725.8 h ha^{-1} to produce 3.7 tons of rice contrary to Group 2 that used 900.3 h ha^{-1} to produce about 3.1 tons.

3.4 Energies in rice production technologies

The results of inputs and outputs energies (MJ ha^{-1}) of rice production technologies per ha were presented in Figure 5 and the percentage composition of each input variables was depict in Figure 6. Results revealed that semi-mechanized farms had total energy inputs of 44,959 MJ per ha while traditional had only 23,666.3 MJ per ha.

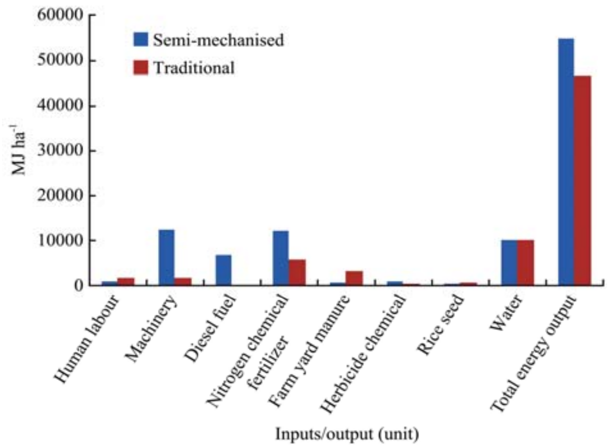

Figure 5 Distribution of amounts of energies inputs and outputs (MJ ha^{-1}) in rice production per hectare

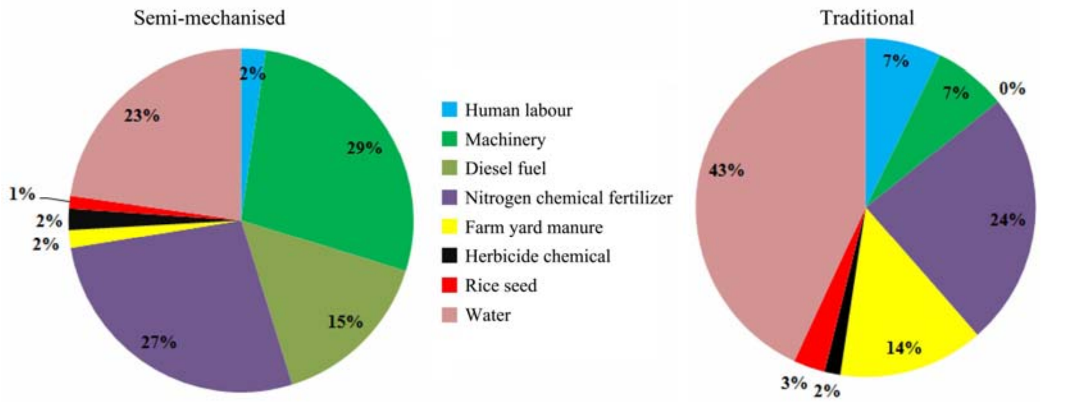

Figure 6 Distribution of percentage (%) composition of energies inputs and outputs in Rice production per hectare

Source: Field survey, 2013/2014.

In semi-mechanized system, machinery and seed material had maximum and minimum energy inputs of 12,358.2 MJ and 524.8 MJ representing 27.5% and 1.2% respectively of total energy used per ha. This was expected as machinery was used for pre-planting operations as well as chemical and fertilizer applications. The results also revealed that herbicide constituted the minimum energy (348 MJ) and water, the maximum energy (10,200 MJ) which translated to 1.5% and 43.1% respectively, in traditional system in the study area. The findings is consistence with results of production of egusi melon in Kwara State, Nigeria (Oladimeji et al., 2016) and watermelon production in Iran (Namdari, 2011) where machinery, nitrogen fertilizer and herbicides had higher share and invariably higher energy in the total inputs of semi-mechanised of these crop production.

3.5 Energy productivity of inputs used in rice production

The energy productivity (kg MJ^{-1}) of inputs used for the two rice production technologies denoted by ratio of rice output (kg ha^{-1}) to each energy input (MJ ha^{-1}) was presented in Table 4. The value of energy productivity for the semi-mechanised inputs ranged from 0.30 (machinery) to 7.11 (rice seed) compared to energy productivity of traditional technology which ranged from 0.31 (water) to 9.11 (herbicide). Therefore, the summary statistics of the energy productivity (EP) of inputs used in both technologies indicated that farmers could improve their EP by using more improved and sophisticated inputs which could boost their rice output. For example, traditional farmers obtained 9.11 kg per MJ of herbicide used. Similarly, semi-mechanised farmers obtained 7.11 kg per MJ for sowing hybrid seeds. However, low EP in semi-mechnised farming was recorded in usage of machinery, diesel fuel and nitrogen fertilizer contrary to a priori expectation. Several studies adduced reasons for low EP in aforementioned inputs. These included non-compliance with recommended fertilizer rate and requirement (NCRI, 2004; Oladimeji and Ajao, 2014) of 250-350 kg ha^{-1} (used 185 kg ha^{-1}), average seed rate (Wilson and Wilson, 1999) of 45-65 kg ha^{-1} (used 35.7 kg ha^{-1}), quite often, surpassed uses of herbicide of 7.4 litres contrary to 4 litres recommended for rice production (NCRI, 2008) and the excessive uses of labour resource in rural areas tend to be a common occurrence due to rather low opportunity cost for the input (Ladipo et al., 1992; Oladimeji et al., 2013a, 2013b). Family labour cannot sensibly be 'laid off'. For instance, in agricultural activities even when it is making a negative contribution, it still had to be catered for whether it is employed or not. Besides, the existence of disguised unemployment and under-employment of labour in rural areas of the country necessarily promoted excess labour in agriculture and fishing enterprises (Oladimeji et al., 2013a)

Table 4 Energy productivity for various inputs used in two rice production technologies

Variables	Semi-mechanised			Traditional		
	TEE (MJ ha^{-1})	EP (kg MJ^{-1})	Rank	TEE	EP	Rank
Human labour	1036.3	0.30	4th	1713.0	1.85	4th
Machinery	12358.2	3.31	5th	1649.0	1.92	3rd
Diesel fuel	6926.1	0.54	6th	-	-	-
Nitrogen	12249.1	0.31	8th	5767.4	0.55	6th
Farm yard manure	777.0	4.80	2nd	3270.1	0.97	5th
Herbicide	888.0	4.20	3rd	348.0	9.11	1st
Rice seed	524.8	7.11	1st	718.8	4.41	2nd
Water	10200.0	0.37	7th	10200.0	0.31	7th

Source: Field survey, 2013/2014; TEE denote Total Energy Equivalent.

3.6 Energy efficiency in rice production

The energy use efficiency, energy productivity, specific energy and net energy of rice production in north central and north western Nigeria were presented in Table 5. The results indicated that the energy use efficiency and energy productivity for semi-mechanised rice production were 1.22 and 0.083 kg MJ^{-1}, while that of traditional system were 1.97 and 0.134 kg MJ^{-1} respectively. The energy productivity implied that 1.22 kg of rice was obtained per unit energy (MJ) in semi-mechanised rice farming which was lower than 1.97 kg per MJ obtained in traditional system. The energy use efficiency ratio of traditional system (1.97) indicated high energy use efficiency compared to the 1.22 of semi-mechanised system. Lower energy used ratio was observed for semi-mechanised mainly because of the additional energy input of farm yard manure, herbicide, diesel fuel and hybrid seed. Hosseini et al. (2014) and Hatirli et al. (2005) opined that the efficient use of energy resources is vital in terms of increasing production, productivity, competitiveness in agriculture as well as sustainability. The results obtained for energy productivity and net energy in both technologies were in tandem with the figures generated by Namdari (2011) on watermelon production (0,134: 0.66 and 17,569.9: 8954.4 respectively) and Oladimeji et al. (2016) on egusi melon production of 0.04:0.03 and 3795.9: 1396.3 respectively. Conversely, the values obtained for specific energy in both technologies (24.2: 29.9) were in sharp contrast with findings of Namdri, (2011) of 1.51 and 1.68 respectively.

Table 5 Level of energy input–output efficiency in rice production

Variables	Unit	Semi-mechanised	Traditional
Total energy output	MJ ha^{-1}	54842.8	46601.9
Total energy input	MJ ha^{-1}	44959.0	23666.3
Yield	kg ha^{-1}	3730.8	3170.2
Energy use efficiency	-	1.22	1.97
Specific energy	MJ kg^{-1}	12.1	7.5
Energy productivity	kg MJ^{-1}	0.083	0.134
Net energy	MJ ha^{-1}	9883.8	22935.6

Source: Field survey, 2013/2014.

3.7 Total energy input in rice production to energy types

Table 6 showed that non-renewable energy (NRE) in semi-mechanised rice production (72.1%) was high compared to that of traditional group (32.8%). This could be as a result of high usage of chemical fertilizer, herbicide, diesel and machinery. This corroborated the studies of Namdari (2011) that estimated non-renewable energy in watermelon to be about 79% and 81% in mechanised and non-mechanised technologies respectively. However, result revealed that direct energy (DE) in semi-mechanised sector (42.1%) was also lower than traditional sector (64.2%). Therefore, rice production among semi-mechanised in the study area was driven by indirect energy while traditional rice production was largely driven by direct energy. Several researchers (Namdaei, 2011; Oladimeji et al., 2016) have found that the ratio of direct energy was lower than that of indirect energy in semi-mechanised farming, and vice versa in traditional one. Likewise, Namdari (2011), Oladimeji et al. (2016, 2017) established that the rate of non-renewable energy was greater than that of renewable energy consumption in watermelon production in Iran, egusi melon and watermelon production respectively in Nigeria.

Table 6 Distribution of total energy input in rice production to energy types

Form of energy (MJ ha^{-1})	Group 1		Group 2	
	Amount of energy	%	Amount of energy	%
Renewable	12538.1	27.9	15901.9	67.2
Non-renewable	32421.4	72.1	7764.4	32.8
Direct	18939.4	42.1	15183.1	64.2
Indirect	26020.1	57.9	8483.2	35.8

Source: Field survey, 2013/2014; Note: direct energy includes: human labour, Farm yard manure, water and diesel fuel; indirect: seeds, chemical fertilizer, herbicides and machinery; renewable: human labour, farm yard manure, water and seed; non-renewable: diesel fuel, chemical fertilizer, herbicide and machinery.

4 Conclusion and recommendations

The study examined profitability and energy use of rice production between semi-mechanized and traditional technologies in two States, Nigeria. The results revealed that the net farm income (profit), energy used per ha, energy output per ha and specific energy were higher in semi-mechanized sector than traditional method. However, renewable energy, direct energy, energy productivity and net energy thrived better in traditional method than semi-mechanized unit. In all, rice farmers are encouraged to shift to semi-mechanized farming for high energy output and increase profitability. Yet, the results of this study also signify that there is need to critically find a way of increasing low energy productivity in both sectors on one hand and increasing renewable energy in semi-mechanize farming on the other hand. Semi-mechanized system should adopt more organic agriculture and local resources to maintain soil fertility and natural processes to manage pests and diseases. The study also suggests that rice farmers should imbibe machinery for pre-planting operations (plough, harrowing and ridging if needed) and introduce integrated weed management system and farm yard manure to control weed and improve crop nutrient and to reduce cost of production. All these could be an impetus to achieve sustainable food sufficient, food security and improve living standard among rice farming households, and possible transition of Nigeria agriculture from subsistence to commercial production to support inclusive economic and human development of new sustainability development goals in developing countries.

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