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Comparative energy use in cassava production under different farming technologies in Kwara State of Nigeria

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ABSTRACT

One of the main components of production expenses in agricultural operations is energy. The effectiveness of its application is frequently impacted in favor of other equally important aspects. The energy utilization in cassava production in three distinct farm sizes and technologies in Kwara State, Nigeria, was investigated using parametric equations. Questionnaires were used to obtain data on output from 175 cassava farmers. Farms were separated into three groups: group 1 (no mechanization), group 2 (partial mechanization), and group 3 (complete mechanization) (full mechanization). There were 92 farms in Group 1 (1–5 ha), 54 farms in Group 2 (6–15 ha), and 29 farms in Group 3 (16–50 ha). Human labor, machinery, diesel fuel, chemicals, seed, and fertilizers as inputs influenced cassava yield. Cassava production used 4904.87 MJ/ha/tonne in small-scale farms, 36352.04 MJ/ha/tonne in medium-scale farms, and 96257.93 MJ/ha/tonne in large-scale farms, according to the study's findings. In the study region, the average energy output of cassava production was 107,632 MJ/ha, 604,800 MJ/ha, and 2,016,000 MJ/ha in the various farms. The energy input-output ratios for the three types of farms were calculated to be 16.13, 16.69, and 20.94 respectively. The Cobb–Douglas function was used to calculate the impacts of inputs on cassava outputs. In medium and large-scale farms, indirect and non-renewable energy contributed significantly more to yield than direct and renewable energy. Human labor, fertilizers, chemicals, and seed were statistically significant contributors to cassava productivity, according to empirical findings.

1. Introduction

Among all root crops grown in Nigeria, cassava (*manihot esculenta*) is the most popular tuber crop. Cassava is native to Brazil and has been widely dispersed in the 16th and 17th centuries in the tropical and subtropical regions of Africa, Asia and the Caribbean (Oni and Oyelade, 2013). It soon became a staple food crop in many of these countries due to its tolerance to drought and poor soil conditions (Ohadike, 2007). In Africa, Asia and Latin America, over 600 million people rely on cassava (Nweke et al., 1988).

Globally, Nigeria is ranked highest in cassava production with about 54 million metric tonnes, therefore cassava production has made significant contribution to the economy of Nigeria (Falola et al., 2016). Cassava also provides food security for families producing and consuming cassava and its products (Akinpelu et al., 2011). It has been referred to cassava as one of most significant tropical crops. Harvested cassava tubers can be processed into many useful products for man, animals and industries (Adekanye et al., 2013).

Since energy resources are costly and scarce, sustainable agriculture needs to increase energy efficiency on the farm. The study of energy indexes in crop production will help identify methods for maximizing energy consumption. Energy is defined as the capacity to do work, and it is required for all production of goods and services (Pishgar-Komleh et al., 2011). Energy in all its different forms is important for improvement of the society (Mohammadi et al., 2010). Crop production uses energy and supplies energy as bio-energy (Ebrahim, 2012). Agricultural energy analysis is increasing tremendously as human population increases hence, energy input and output relationship are necessary if adequate food and fiber must be provided to cater for the population. Energy use in agriculture depends on population involved, amount and size of cultivable lands, and stage of technology. Seeds, fertilizers, machinery, chemicals, human labour and diesel fuel used account for the energy inputs in agricultural production. Agricultural productivity is directly proportional to energy inputs (Mohammadi et al., 2010). Bayramoglu and Gundogmus (2009) opined that sustainability of agriculture largely depends on amount of energy input.

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Farm performance prediction is helpful for farmers, states, and agribusiness sectors. It helps to make marketing choices for farmers. For their buying and storage decisions, processors of food, and others in the marketing chain, need forecasts.

Many researchers have worked on crop energy input-output. Demircan et al. (2006) studied analyzed energy inputs in sweet cherry production. Naeimeh et al. (2011) investigated energy use garlic production in Iran. Mohammadi and Omid (2010) examined energy inputs in cucumber production. Mousavi-Avval et al. (2011) modeled energy flow in canola production. Rajabi–Hamedani et al. (2011) assessed energy use in potato production. Heidari and Omid (2011) used data envelopment method to determine efficiency of greenhouses. Pishgar-Komleh et al. (2012) examined energy use and CO_2 emission in potato production. Oladimeji et al. (2016) estimated energy use in ‘egusi’ melon production in Nigeria. Ansari et al. (2017) examined energy efficiency of wheat crop under different climate and soil based irrigation schedules. Alireza et al. (2018) researched on sensitivity analysis of energy inputs in crop production using artificial neural networks. Adekanye et al. (2020a), analyzed energy use in cassava production in North-Central Nigeria. Adekanye et al. (2020b) researched on the energy efficiency and use of a parametric method for poultry production in Kwara State, Nigeria.

However, there is presently a dearth of research information on crop-energy input in Nigeria (2010). Ibrahim and Ibrahim (2012) concluded that although there is no report on crop energy use pattern in the country, yet such studies are necessary to combat hunger facing the populace. Therefore, the objective of this study was to investigate cassava energy use pattern in three different farm sizes and technologies using Cobb–Douglas function. Furthermore, impacts of each of the inputs on yield was determined and the correlation among various energy inputs and output was also examined.

This study involved energy expenditure in cassava production from tillage to harvesting, without considering other types of energy like rain, radiation, wind, etc. Age of equipment and machinery used in cassava production, energy used in processing cassava into different products and that used to transport farm materials to and from the farm was beyond the scope of this study. Generally, energy inputs in crop production are distinctly referred to as direct energy, indirect energy, renewable energy and non-renewable energy. Diesel fuel, electricity and human labour used in crop production processes represent direct energy (Farzad and Mohammed, 2012; Mobtaker et al., 2012). Indirect energy includes corporate energy in farmyard manure, machinery, fertilizers, seed, and chemicals. Fertilizers, chemicals, diesel fuel, and machinery represent non-renewable energy. Human labour, seeds and manure are grouped as renewable energy (Rajabi-Hamedani et al., 2011).

2. Methods

This study was carried out in Kwara State, Nigeria. Kwara State is located in the North Central part of Nigeria. It lies between latitudes 7°45 N and 9°30 N and longitudes 2°30 E and 6°25 E (Oladimeji et al., 2016). Data used in this study were collated from 2013 to 2016 through questionnaires designed to obtain information on variables used in cassava production. Sample size was determined using the method described by Pishar-Komeh et al. (2012).

$$n = \frac{\left(\sum N_h S_h\right)}{N^2 D^2 + \sum N_h {S_h}^2} \tag{1}$$

Where;

N = required sample size, N = number of farmers in the target population, N_h = number of farmers in the ‘h’ stratification, ${S_h}^2$ = variance of the ‘h’ stratification, d = permitted error ratio deviated from average of population, z = reliability coefficient (1.96 which represent 95% confidence), $D^2 = d^2/z^2$ = permissible error in the sample population, defined to be 5% within 95% confidence interval. A total of 175 cassava farmers were randomly selected for the study.

Variables used for cassava production were specifically outlined to determine energy equivalent of each. Inputs used in the surveyed farms included chemicals, human labour, machinery, diesel fuel, chemical fertilizers, seed and tubers (roots) as output. Energy equivalents of inputs and output in Table 1 were used to calculate amount of inputs used. Equation (2) was used to calculate energy inputs by machines (e.g. tractors) per unit area.

$$ME = \frac{ELG}{TC_a} \text{ (Pishgar – Komleh et al., 2012)} \tag{2}$$

Where; ME = machine energy (MJ/ha), G = weight of machine (kg), E = production energy of machine (MJ/kg/yr), L = useful life of machine (year), T = economic life of machinery (h) and C_a = effective field capacity (ha/h).

Output – input ratio, energy productivity and specific energy for cassava production were calculated by using Eqs. (3)–(5) to explore output – input energy and different forms (Mobtaker et al., 2012; Morteza et al., 2012; Hossein et al., 2013):

$$\textit{Energy use efficiency} = \frac{\textit{Energy output } (MJ\ ha^{-1})}{\textit{Energy input } (MJ\ ha^{-1})} \tag{3}$$

$$\textit{Energy productivity} = \frac{\textit{Cassava output } (kg\ ha^{-1})}{\textit{Energy input } (MJ\ ha^{-1})} \tag{4}$$

$$\textit{Specific energy} = \frac{\textit{Energy input } (MJ\ ha^{-1})}{\textit{Cassava output } (kg\ ha^{-1})} \tag{5}$$

Cobb-Douglas function (Cobb and Douglas, 1928) was used to determine the correlation between energy inputs and yield. Cobb - Douglas production function is expressed in general form as follows.

$$Y = f(x)\exp(u) \text{ (Mobtaker et al., 2012)} \tag{6}$$

Eq. (6) can be transformed to Eq. (7):

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i i = 1, 2, 3....n \tag{7}$$

Where Y_i denotes the yield of the ith farmer, X_{ij} the vector of inputs used in the production process, a, constant term, α_j represents coefficient of

Table 1
Energy equivalents of inputs and output in agricultural production.

Variables	Unit	Energy equivalent, MJ	Source
Inputs			
Human labour			
Man	Man-h	1.96	Hossein et al. (2013)
Woman	Woman-h	1.57	Hossein et al. (2013)
Machinery	kg	62.7	Hossein et al. (2013)
Diesel fuel	L	47.8	Hossein et al. (2013)
Chemical fertilizer	kg		
Nitrogen		66.14	Oladimeji et al. (2016)
Phosphate		17.44	Oladimeji et al. (2016)
Potassium		13.72	Oladimeji et al. (2016)
Chemicals	kg		
Pesticides		199	Morteza et al. (2012)
Herbicides		238	Morteza et al. (2012)
Fungicides		216	Morteza et al. (2012)
Output			
Cassava sticks	kg	5.6	Adekanye et al. (2020a)

inputs which are estimated from the model and e_i is the error term.

Assuming that when the energy input is zero, cassava production is also zero, Eq. (7) changed to Eq. (8):

$$\ln Y_i = \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i i = 1, 2, 3....n \tag{8}$$

Eq. (8) can be expressed as Eq. (9), with the assumption that a yield is a function of inputs energy:

$$\ln Y_i = \alpha_1 + \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + e_i \tag{9}$$

Where; X_1 = seed energy input, X_2 = human labour energy input, X_3 = machinery energy input, X_4 = diesel fuel energy input, X_5 = fertilizers energy input and X_6 = chemical energy inputs.

Cobb – Douglas function was also applied to assess the effects of direct, indirect, renewable and non-renewable energy as follows:

$$\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i \tag{10}$$

$$\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \tag{11}$$

Where;

Y_i = yield of the ith farmer, DE = direct energy inputs, IDE = indirect energy inputs, RE = renewable energy inputs, NRE = non-renewable energy used for cassava production, β_1 and γ_1 = coefficients of variables and e_i is the error term.

Eq. (9), Eq. (10) and Eq. (11) were determined by using ordinary least square method. Information obtained from farmers was recorded into Excel spreadsheet and analyzed with R software.

3. Results and discussion

3.1. Management practices in cassava farms in the study farms

Management practices for cassava cultivation in the study area along with time periods of these practices are presented in Table 2. Group I (small-scale farms) and Group II (medium-scale farms) cassava farmers employed manual labour mostly for tillage operations, planting, weeding, fertilizer application and harvesting. Group III farmers (large scale) used manual labour and machinery for these operations; however, machinery was used for transportation of harvested tubers and farm workers during the growing season. All the farmers in this study planted TMS 419 variety of cassava.

3.2. Analysis of energy usage and indices in cassava production

Table 3 shows average amount of inputs used in the cassava production and outputs. Energy equivalents of inputs and output, per hectare basis in the farm groups are presented in Table 4. It was observed from Table 4 that total energy used (MJ/ha) in field operations were 74999.62 and 672,000 MJ/ha. Total energy input for various processes in small scale, medium scale and large-scale farms were calculated to be 6673.21, 36352.04 and 96257.93 MJ/ha respectively. In similar studies, Mohammadi et al. (2010) and Rajabi–Hamedani et al. (2011) obtained 68,928 MJ/ha and 39232.79 MJ/ha respectively for corn grain production in Iran. Bamgboye and Babajide (2015) obtained 7388.6 MJ/ha from a study of ten small-scale cassava farmers in Oyo State, Nigeria. obtained 4950 MJ/ha for cassava production in Thailand. Pishgar - Komleh et al. (2011) calculated 47,000 and 79,300 MJ/ha for potato. Table 4 also shows that energy input and output differs from one group to another group. This is because farm sizes determine the amount of inputs required (2015).

Table 4 also shows distributions of different energy used in the cassava farms. Energy equivalents of 120, 162 and 164 MJ/ha of human power were used to cultivate 1 ha of cassava in small, medium and large-scale farms while 130 and 123 MJ/ha of machine power were used respectively in medium and large-scale farms. Pishgar – Komeh et al. (2012) concluded that 911.2 MJ/ha, 914.2 MJ/ha and 910.6 MJ/ha of human power were consumed in potato production. Pishgar-Komleh et al. (2011), human labour inputs varied between 90.56 and 421.5 MJ/ha. Bamgboye and Babajide (2015) opined that reduced energy inputs will results to reduced yields.

Results in Table 4 also revealed that energy equivalent of 7472.57 and 13527.4 MJ/ha of diesel fuel were used in medium and large-size farms. Diesel energy input increased in medium and large size farms because many respondents in these groups used more machinery while farmers in small - scale category did not. Machines for ploughing, harrowing and ridging operations required diesel to operate and tractors were used to transport farm workers (labourers) and harvested crops. Result also reveals that cassava production in the study area still depends largely on manual labour as a large percentage of cassava farmers are in the small-scale category. Human labour was mostly employed for land preparation, planting operations, weeding operations, chemical/fertilizer applications and harvesting operations.

Table 5 presents energy indices and amount of different energy forms used in the production. Energy ratio for each farm group was estimated as 16.13, 16.69 and 20.94. Energy use efficiency increased with farm size. This implies that large size farms used energy efficiently. These agree with the submissions by Pishgar-Komleh et al. (2011) and Woods et al. (2010). Canakci et al. (2005) obtained 2.8 for wheat.

Table 2

Management practices of cassava in the study area.

Operation	Small farms	Medium farms	Large farms
Land preparation period	February–March	February–March	February–March
Ploughing	Nil	Moldboard plough,	Moldboard plough,
Harrowing	Nil	Disc harrows	Disc harrows
Tractor used	Nill	MF 55hp	MF 55hp, MF 75hp
Planting time	April–August	April–August	Late March – Early September
Planting method	Manual	Manual	Manual, planter
Fertilizer and pesticide application	Manual (knapsack sprayers)	Manual (knapsack sprayers)	Manual and Boom sprayer
Weeding	Manual (cutlass and hoe)	Manual (cutlass and hoe)	Manual
Harvesting	Manual (cutlass)	Manual (cutlass)	Manual (cutlass), Harvester

Table 3

Average amount of input and output in the cassava Farms.

Inputs	Farm size groups (ha)		
	Group 1	Group 2	Group 3
A. Inputs			
1. Human labour	61.45	82.65	83.86
2. Machinery	–	2.07	1.96
3. Diesel fuel	–	156.3	283
4. Fertilizers			
a) Nitrogen (N)	3.72	17.45	76.43
b) Phosphate (P205)	10.51	23.74	111.76
c) Potassium (k20)	10.06	30.18	74.56
5. Chemicals			
a) Herbicides	1.49	1.73	1.73
b) Pesticides	1.52	1.67	1.67
c) Fungicides	0.77	1.65	1.65
6. Seed	606.01	13022.41	9481.35
Total inputs	695.53	13339.88	10117.97
B. **Output**			
Cassava output (kg)	19,220	108,000	360,000

Table 4
Average energy inputs and output in cassava production per hectare (MJ/ha).

Inputs	Farm size groups (ha)		
	Group 1	Group 2	Group 3
1. Human labour	120.44	162.01	164.36
2. Machinery		129.80	122.90
3. Diesel fuel	–	7472.57	13527.4
4. Fertilizers			
Nitrogen (N)	246.04	1154.14	5055.74
Phosphate (P_20_5)	183.29	414.02	1949.09
Potassium (k_20)	138.02	414.06	1412.47
5. Chemicals			
Herbicides	354.62	411.74	411.74
Pesticides	302.48	332.33	332.33
Fungicides	166.32	356.4	356.4
6. Seed	3393.66	25393.37	72925.5
Total energy input	6673.21	36240.43	96257.93
Total energy output	107,632	604,800	2,016,000

Table 5
Energy input – output ratio in cassava production.

Energy ratio	Unit	Group 1	Group 2	Group 3
Energy use efficiency	–	16.13	16.69	20.94
Energy productivity	MJ/ha	2.88	2.98	3.74
Net energy	MJ/ha	100,959	568,560	1,919,742
Energy forms				
Direct energy[a]	MJ/ha	120	7634.56	13691.76
Indirect energy[b]	MJ/ha	4784.77	28605.9	82566.16
Renewable energy[c]	MJ/ha	3514.1	25555.4	73089.86
Non-renewable energy[d]	MJ/ha	1390.77	10685.1	23168.06
Total energy input	MJ/ha	6673.21	36240.4	96257.93
Energy output	MJ/ha	107,632	604,800	2,016,000

Note: a: includes human labour and fuel; b: includes seeds, machinery, chemicals and fertilizers; c: includes human labour and seeds; d: includes diesel fuel, chemicals, fertilizers and machinery.

Rajabi-Hamedani et al. (2011) obtained 1.25 for potato. Pishgar-Komleh et al (2012) obtained 1.71 for wheat.

Average energy productivity of the three groups of farms was 2.88, 2.98 and 3.74 kg/MJ. This implies that 3.74 kg of cassava was produced per unit energy (MJ) in large scale farms. Hence, large scale farms can produce 0.52 kg and 0.76 kg output more than small and medium scale farms respectively. It was observed that energy productivity and net energy increased significantly as size of farms increased (Fig. 1). This can be as a result of level of mechanization and management practices (Rajabi–Hamedani et al., 2011). Hossein et al. (2013) estimated energy productivity of stake tomato and cotton to be 0.02 and 0.06 respectively. Yilmaz et al. (2005) obtained 0.06 for cotton and Erdal et al. (2007) obtained 1.53 for sugar beet.

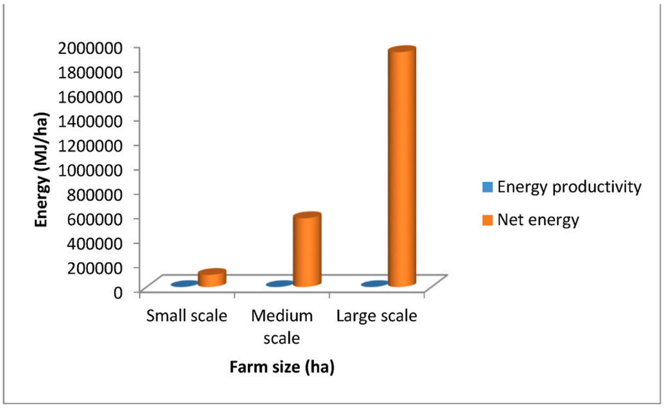

Fig. 1. Energy productivity and net energy in the cassava farms.

3.3. Model estimation of cassava production

Tables 6–8 present results of regression analysis for Eqs. (9)–(11) as Model I, II and III. Results revealed that each energy variable had different effect on cassava production. It was observed that certain energy inputs had positive effects on yield and chemicals had negative impacts on yield. Data collected in this study is cross-sectional. Durbin-Watson test was used to test for autocorrelation (Hossein et al., 2013) to establish that there was no correlation. The Durbin-Watson values obtained in all the three models were less than 2, implying that there was no autocorrelation in the models at 5% significance level.

3.3.1. Results of model I

Human labor, chemical, fertilizer and cassava stem were significant and had positive effects on cassava yield (Table 6). This implies that the dependent variables of the model in the case of Group I Farms all had positive effects on the energy output. That is, an increase in any of the variables will result to an increase in the energy output. Also, R-squared value for model I was estimated as 0.81 showing that about 81% of the variability in the total yield was predicted by the model equation. Durbin Watson Statistic indicates an absence of autocorrelation at 5% significant level. For Group II Farms, all the coefficients had positive effects on cassava yield except chemical energy input (−0.007). This implies that increase in human labor, fertilizer, cassava stem, machinery and fuel energies will increase the amount of output while an increase in chemical energy inputs will reduce output by 0.007%. Fertilizer, cassava stem and machinery variables were significant at 0.1%, 1% and 5% significant level respectively. The R-squared value was 0.93 in this case and the Durbin Watson statistic indicates no autocorrelation at 5% significant level.

For Group III Farms, all the coefficients had positive effects on cassava production. Human labour and chemical energies were significant at 5% and 0.1% respectively. The variable with the highest impact was cassava stem followed by machinery. It can therefore, be concluded that an increase in any of the variables for this Group will lead to an increase in the energy output. The R-squared value was 0.95 and the Durbin Watson Statistics indicate no autocorrelation at 5% significant level. Maximum variance inflation factor for each group was less than 10; hence, independent variables in are not related. White test statistic showed that there is no heteroscedasticity.

3.3.2. Results of model II

Table 7 presents analysis of direct energy (DE), indirect energy (IDE), renewable (RE) and non-renewable (NRE) energies. Impacts of direct and indirect energies were 0.114 and 0.029, respectively in Group I farms. These results indicated that an increase in the different forms of energies led to 0.114% and 0.029% increase in cassava yield. The Durbin-Watson statistic was 1.83 at 5% significant level (no autocorrelation) while the R-squared value was 0.89. Table 7 also revealed that indirect energy (IDE) had more impact than direct energy (DE) in group II and group III farms. This result was similar with (Mousavi-Avval et al., 2011) and (Woods et al., 2010).

For Group II farms, DE (0.035) and IDE (0.87) were positive with the variable of highest impact being IDE (0.87). Thus, an increase in either variable implies an increase in the energy output. The coefficients of both variables were significant at 5% and 0.1% significant level respectively. The Durbin-Watson and R-squared value was 1.88 and 0.89 respectively at 5% significant level.

For Group III farms, both coefficients, DE (0.132) and IDE (0.45) were positive with the variable of highest impact being IDE (0.45). The coefficients of both variables were significant at 0.1% and 1% significant levels respectively. The Durbin-Watson statistic was 1.86 at 5% significant level showing no autocorrelation while the R-squared was 0.87. Maximum variance inflation factor (VIFmax) was observed to be less than 10 indicating that independent variables are not related. White test statistic showed that there is no heteroscedasticity.

Table 6
The estimation results for Model I and their coefficients.

$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + e_i$
Model 1:

Farm		Small farms			Medium farms			Large farms	
Independent Variables	$\propto_i$	*t*	*P value*	$\propto_i$	*t*	*P value*	$\propto_i$	*t*	*P value*
Human Labour	0.18	7.523	0.001564 **	0.017	1.879	0.06660	0.144	2.645	0.0148*
Chemical	0.02	3.264	0.000593 ***	−0.007	−0.784	0.437	0.045	5.45	1.83e-05 ***
Fertilizer	0.016	3.522	0.000682 ***	0.259	7.794	5.97e-10 ***	0.028	0.767	0.4513
Cassava Stem	0.95	9.044	3.33e-14***	0.647	3.318	0.0018 **	0.714	0.074	0.4826
Machinery				0.664	2.398	0.0218 *	0.271	1.078	0.293
Fuel				0.173	1.082	0.285	0.011	0.038	0.970
R^2	0.892			0.926			0.952		
Durbin-Watson	1.82			1.73			1.83		
VIF_{max}	6.86			7.47			7.52		

Note: *** significance at 0.1%, ** significance at 1%, *significance at 5%.

Table 7
Estimation for model II and their coefficients.

$\ln \boldsymbol{Y_i} = \boldsymbol{\beta_1} \ln \boldsymbol{DE} + \boldsymbol{\beta_2} \ln \boldsymbol{IDE} + \boldsymbol{e_i}$
Model II:

Farm		Group 1			Group 2			Group 3	
Independent Variables	β_i	*t*	*P value*	β_i	*t*	*P value*	β_i	*t*	*P value*
DE[a]	**0.114**	**0.95**	**0.335**	**0.035**	**2.117**	**0.0393** [e]	**0.132**	**12.008**	**4.13e-12** [c]
IDE[b]	**0.029**	**11.54**	**<2e-16** [c]	**0.872**	**12.196**	**<2e-16** [c]	**0.45**	**2.781**	**0.00994** [d]
R^2			**0.811**			**0.885**			**0.875**
Durbin-Watson			**1.81**			**1.88**			**1.86**

Note.
[a] Includes human labour and diesel fuel energies.
[b] – includes machinery, fertilizer, seeds and chemical energies.
[c] Significance at 0.1%.
[d] Significance at 1%.
[e] Significance at 5%.

Table 8
Estimation for model III and their coefficients.

$\ln \boldsymbol{Y_i} = \gamma_1 \ln \boldsymbol{RE} + \gamma_2 \ln \boldsymbol{NRE} + \boldsymbol{e_i} + \; + \gamma_1 \ln \boldsymbol{NRE} + \boldsymbol{e_i}$
Model III:

Farm		Group 1			Group 2			Group 3	
Independent Variables	γ_i	*t*	***P value***	γ_i	*t*	*P value*	γ_i	*t*	***P value***
RE	0.298	3.696	0.000376[a]	0.112	2.61	0.0119 [c]	0.104	10.26	1.24e-10 [a]
NRE	0.104	10.906	<2e-16 [a]	0.345	12.9	<2e-16 [a]	0.725	0.703	0.488[b]
R^2			0.741			0.893			0.838
Durbin-Watson			1.973			1.83			1.544

Note.
[a] Significance at 0.1%.
[b] Significance at 1%.
[c] Significance at 5%.

3.3.3. Results of model III

Table 8 presents estimations of Model III. In Group I, renewable energy (RE) and non-renewable energy (NRE) were positive with RE having the greatest impact and is statistically significant at 0.1% significant level in group I farms. This means that an increase in either RE or NRE will result to an increase in the energy output. The Durbin-Watson statistic was 1.97 at 5% significant level (no autocorrelation) while the R-squared is 0.841.

For Group II farms, renewable energy (0.112) and nonrenewable energy (0.345) had positive effects on cassava yield with the variable of highest impact being nonrenewable energy (0.345). Thus, an increase in either variable implies an increase in the energy output. The coefficients of both variables were significant at 5% and 0.1% respectively. The Durbin-Watson statistic was 1.88 at 5% significant level indicating absence of autocorrelation while the R-squared value was 0.885.

For Group III farms, renewable energy (0.104) and nonrenewable energy (0.725) had positive effects on cassava yield. Thus, an increase in either energy results to an increase in the energy output. The renewable energy input was significant at 0.1%. The Durbin-Watson statistic is 1.97 implying no autocorrelation at 5% significant level while the R-squared is 0.841.

4. Conclusions

In this study, energy consumption in cassava production under different farming technologies in Kwara State, Nigeria was examined. Cobb-Douglas parametric approach was used to analyze comparative energy use in cassava production under different agricultural systems. The population studied was divided into three strata based on the ownership of tractors and farm machinery, as well as the level of farming technology. Results revealed that cassava production in the study area consumed a total energy of 4904.87 MJ/ha in small-scale farms, 36352.04 MJ/ha in medium-scale farms and 96257.93 MJ/ha in large-scale farms. Average energy outputs were 107,632 MJ/ha, 604,800 MJ/ha and 2,016,000 MJ/ha respectively. Energy ratio for each group was 16.13, 16.69 and 20.94. Energy productivity for the three group of farms were 2.88 MJ/ha, 2.98 MJ/ha and 3.74 MJ/ha while net energy was estimated to be 100,959 MJ/ha for small-scale farms, 568,560 MJ/ha for medium-scale and 1,919,742 MJ/ha for large-scale farms. It was discovered that large-scale farms utilized energy efficiently than medium and small-scale farms.

Indirect energy and non-renewable energy had higher impacts in medium and large-scale farms than direct energy and renewable energies. The reverse was the case in small-scale farms. Therefore, lowering the total NRE ratio, particularly the use of chemical fertilizers, would have a positive impact on the sustainability of cassava production as well as other positive environmental effects. Appropriate fertilizer, diesel, and other key input use would be beneficial not only in eliminating negative environmental and human health consequences, but also in sustaining sustainability and lowering production costs.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Timothy Adekanye reports administrative support, equipment, drugs, or supplies, statistical analysis, and travel were provided by Landmark University. Timothy Adekanye reports a relationship with Landmark University that includes: employment, non-financial support, and travel reimbursement. Timothy Adekanye has patent pending to Timothy Adekanye.

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