# Analysis of energy use in cassava production in North-Central Nigeria

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**Abstract:** Energy inputs and yield relationship in cassava production was investigated to establish correlation between inputs and outputs in cassava production in Nigeria. Production data of energy inputs and crop yields were collected from 54 cassava farms in twelve cassava producing villages through site visits, interaction with the farmers and physical measurements for three production seasons (2013-2016). The data were analyzed statistically. Amount of inputs per hectare were calculated and multiplied by coefficients of energy equivalents. Total energy inputs in cassava production were 36482.8 MJ ha$^{-1}$ while average output of cassava tubers was 32022.6 kg ha$^{-1}$. Energy use ratio, energy productivity and specific energy of the surveyed farms were 4.9, 0.9 kg MJ$^{-1}$ and 1.1 MJ kg$^{-1}$ respectively. Shares of direct and indirect energy inputs were 5.7% and 94.2% respectively. Human labor, fertilizer, cassava stem, machinery and fuel had positive effects on output. Fertilizer, cassava stem and machinery variables were significant at 0.1%, 1% and 5% significant levels respectively. R-squared was 0.93 and Durbin Watson statistic indicates no autocorrelation at 5% significant level, indicating that variables in the model were not dependent of each other and changes in the value of one variable did not have any meaningful effect on other variables. All the variables contributed independently to the output.
**Keywords**: agriculture, energy ratio, cassava, output, Cobb-Douglas

**Citation:** Adekanye, T. A., K. C. Oni., E. A. Alhassan., A. O. Adekiya and A. Olayanju. 2020. Analysis of energy use in cassava production in North-Central Nigeria. Agricultural Engineering International: CIGR Journal, 22 (2):?-?.

## 1 Introduction

Cassava (*Manihot esculenta*) is a tropical root crop that thrives well in humid tropics and one of the crops adapted to conditions of low soil nutrients and ability to survive drought (Franklin and Kue, 2015). Cassava can be successfully grown on marginal soils. It is produced all year-round and can tolerate extreme stress conditions. Cassava is one of the most useful crops to a larger majority of Nigerians and has been classified as one of the most important food staples in Africa (Adekanye et al., 2013). In Nigeria, cassava plays a significant role in alleviating food shortage because it is produced by almost all farmers in the country (Oni and Oyelade, 2013). As at 2010,

four topmost cassava producing nations were Nigeria, Bazil, Indonesia, and Thailand (Oppong, 2013). However, it has been observed that Nigeria is the highest cassava producing nation in terms of volume of cassava production

**Received date:** 2019-03-05 **Accepted date:** 2019-09-09
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not in terms of yield per hectare. Consequently, Nigeria is ranked 8th position in terms of cassava yield (kg $ha^{-1}$) behind Brazil and Thailand. Management practices of cassava production and varieties of cassava planted in Nigeria may be responsible for low yield per hectare in the country (FAO, 2014).

Energy is very important for all production processes; hence, it is important to the survival of man and requisite for the improvement of the society at large (Pishgar-Komleh et al., 2012). Energy is linked to agriculture. Agriculture uses energy and produces it as a biological energy (Ozkan et al., 2004). Attention on energy inputs in crop production is increasing with respect to increasing global population and increasing demand for food production to cater for the increasing population. Effective energy input in agriculture is necessary to enhance agricultural production (Kizilaslan, 2009). Improved crop production is a function of amount and efficient application of energy (Handan et al., 2009). This is because crop yield and food supply are dependent on energy inputs during production. Also, energy input in the agricultural sector depends on the amount and type of land, number of farm workers, and level of mechanization (Bayramoglu and Gundogmus, 2009).

Energy expenditure in agriculture is a function of the technology application and volume of production. Seed, machinery, fertilizer, chemical, diesel fuel, and electricity contribute significantly to energy supplies in agricultural production system. Ebrahim (2012), Hamid and Aref (2015) opined that agricultural production was directly proportional to amount of energy inputs, mechanization status and management practices adopted by the farmers.

Energy inputs in agricultural production are classified as direct energy, indirect energy, renewable energy and non-renewable energy forms. Direct energy is mainly adopted for crop management. It is used for tillage operations, planting, weeding, irrigation, inter-culture, harvesting, threshing, and transportation. Indirect energy represents energy supplied from seed, chemicals, farmyard manure, fertilizers, and machinery (Beheshsti-Tabar et al., 2010). Machinery, diesel, fertilizers, and chemicals inputs are classified as non-renewable energy and while manure, human labor and seed are classified as renewable energy. Farzad and Mohammed (2012) concluded that crop production utilized more direct energy.

Many researchers have worked on energy analysis to determine energy efficiency of different crops and animal products such as on energy balance of chickpea (Marakoglu et al., 2010; Baran and Gokdogan, 2017), energy use and yield in potato (Mohammadi et al., 2008; Raja et al., 1997), energy input in cucumber production (Mohammadi and Omid, 2010). Heidari et al. (2012) determined the efficiency of greenhouses in Iran. Mousavi-Avval et al. (2011) studied the energy flow modeling and sensitivity of input for canola production. There is insufficient data on energy expenditure in the agricultural sector in Nigeria. This is as a result of the fact that researchers have not carry out much study on analysis of energy input in crop production in Nigeria. Therefore, it is difficult to identify useful energy inputs and plan for the preservation of crops required by the increasing population (Ibrahim and Ibrahim, 2012). Thus, a need to evaluate energy expenditure in cassava production in Kwara State is necessary (Adekanye, 2018). The focus of this research was to investigate the correlation between inputs and output in cassava production and to estimate empirical model equations for cassava yields. The model equations will reveal the correlation between each input and output. This study was also aimed to investigate the relationship between cassava yield and other types of energies using functional forms.

## 2 Materials and methods

This study was conducted on selected cassava farms in Kwara State (latitudes 7°45N and longitudes 2°30E). The State was purposely selected for this study because cassava is a prominent crop produced by the farmers in the State. Data were collected from 54 cassava farms through visits, interaction with the farmers and physical measurements for three production seasons (2013-2016). Population size was determined by using method used by Morteza et al. (2012):

$$n = \frac{N(s\times t)^2}{(N-1)d^2+(s\times t)^2} \quad (1)$$

Where 'n' is the required sample size, 's' is the standard deviation, 't' is the t value at 95% confidence limit (1.96), 'N' is the number of holdings in target population and 'd' is the acceptable error (permissible error was chosen as 5%).

All the variables used in the production were identified to determine energy equivalents. These variables included fertilizers, human labor, machinery, diesel fuel, seed and chemicals. Amounts of inputs used per hectare and outputs were estimated and multiplied with the coefficient of energy equivalents (Table 1). Machine energy inputs per hectare were estimated using Equation 2:

$$ME = \frac{ELG}{TC_a} \quad (2)$$

Where;

ME = machine energy (MJ ha$^{-1}$), G = weight of machine (kg), E = production energy of machine (MJ kg$^{-1}$ yr$^{-1}$), L = useful life of machine (year), T = economic life of machinery (h) and $C_a$ = effective field capacity (ha h$^{-1}$).

**Table 1 Inputs and output energy equivalents in crop production**

| Variables | Unit | Energy equivalent (MJ) | Source |
|---|---|---|---|
| Inputs | | | |
| Human labour | | | |
| Man | Man-h | 1.96 | Mobtaker et al., 2012 |
| Woman | Woman-h | 1.57 | Mobtaker et al., 2012 |
| Machinery | kg | 62.7 | Kizilaslan, 2009 |
| Diesel fuel | L | 47.8 | Heidari and Omid, 2011 |
| Nitrogen | kg | 66.14 | Mousavi et al., 2010 |
| Phosphate | kg | 17.44 | Mobtaker et al., 2012 |
| Potassium | kg | 13.72 | Demircan et al., 2006; Mobtaker et al., 2012 |
| Pesticides | kg | 199 | Zangeneh et al., 2010 |
| Herbicides | kg | 238 | Zangeneh et al., 2010 |
| Fungicides | kg | 216 | Zangeneh et al., 2010 |
| Cassava sticks | kg | 5.6 | Pimentel, 1999; Demircan et al., 2006 |

Equations 3 to 5 were used to estimate output-input energy in cassava production:

$$Energyuseefficiency = \frac{Energyoutput(MJ/ha^{-1})}{Energyinput(MJ/ha^{-1})} \quad (3)$$

$$Energyproductivity = \frac{Cassavaoutput(kg/ha^{-1})}{Energyinput(MJ/ha^{-1})} \quad (4)$$

$$Specificenergy = \frac{Energyinput(MJ/ha^{-1}\ )}{Cassavaoutput(kg/ha^{-1})} \quad (5)$$

Correlation between each energy input and output was determined by using Cobb-Douglas function. In general form, Cobb -Douglas function is expressed as Equation 6:

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

Equation (6) can be expressed as Equation 7:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln\left(X_{ij}\right) + e_i \quad (7)$$

Where;

$Y_i$ = yield of the i$^{th}$ farmer, $X_{ij}$ = the vector of inputs used in the production,

a = the constant term, $\alpha_j$ = coefficient of inputs (estimated from the model), $e_i$ = the error term.

Since output depends on inputs, Equation 7 can be written as Equation 8:

$$\text{Ln}\, Y_i = \alpha_1 + lnX_1 + \alpha_2 lnX_2 + \alpha_3 lnX_3 + \alpha_4 lnX_4 + \alpha_5 lnX_5 + \alpha_6 lnX_6 + e_i \quad (8)$$

Where;

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

In Cobb-Douglas function, return to scale is the summation of the elasticities obtained from the regression of coefficients. If it is more than, equals to or less than 1, then increasing, constant or decreasing returns to scale will be obtained. Data obtained from the surveyed farms were processed using R software.

**Table 2 Management practices for cassava in the study area**

| Operations /practices | |
|---|---|
| Name of cassava variety | TMS 419 |
| Tractor used | MF 55HP |
| Land preparation period | February – March |
| Ploughing | Moldboard plough |
| Harrowing | Disc harrows |
| Planting time | April – August |
| Planting method | Manual |
| Fertilizer and pesticide application | Manual (knapsack sprayers) |
| Weeding | Manual (cutlass and hoe) |
| Harvesting | Manual (cutlass and hoe) |

Table 2 shows the management practices for cassava cultivation in the study area along with time periods of these practices. Cassava farmers in this study employed manual labor mostly for planting, weeding, fertilizer application and harvesting.

## 3 Results and discussion

Table 3 shows the average value of inputs and outputs in cassava production. The table shows that the average human labor, machine power and diesel fuel required in the study area was 104.43 h ha$^{-1}$, 40.11 h ha$^{-1}$ and 39.52 L ha$^{-1}$ respectively. Table 4 presents energy equivalents of inputs and output per hectare. In Table 4, total energy used in various operations during cassava production was 36482.8 MJ ha$^{-1}$ while energy output was 179326.8 MJ ha$^{-1}$. In similar studies, Bamgboye and Babajide (2015) obtained 7388.6 MJ ha$^{-1}$ from a similar study while Chamsing et al. (2006) obtained 4950 MJ ha$^{-1}$ for cassava production in Thailand. Pishgar-Komleh et al. (2012) calculated 47000 MJ ha$^{-1}$ as input energy and 79300 MJ ha$^{-1}$ as output energy for potato production in Iran. These differences in results may be due to differences in the amount of inputs (biological and chemical energy) and differences in means of acquiring equipment (Bamgboye and Babajide, 2015).

Table 4 also shows that to cultivate a hectare of cassava in the study farms, energy equivalent of 204.6 and 1887.6 MJ ha$^{-1}$ of human power and diesel energy were used while 2515.7 MJ ha$^{-1}$ of machine power were used in the farms. In the study conducted by Bamgboye and Babajide (2015), human labor varied between 90.56 and 421.5 MJ ha$^{-1}$. Woods et al. (2010) observed that low energy inputs resulted in lower outputs. Diesel was required to power the machinery for field operations like ploughing, harrowing and ridging. Sometimes, tractor is used to convey farm workers (laborers) and harvested crops. The result also reveals that cassava production in the study area still depends largely on manual labor. Human labor was mostly employed for land preparation, planting operations, weeding operations, chemical / fertilizer applications and harvesting operations.

Furthermore, estimated values for energy ratio, energy productivity and specific energy in the surveyed farms were 4.9. 0.9 and 1.1 MJ kg$^{-1}$ respectively (Figure 1). Nitrogen fertilizer has the largest share (45.7%) of the total energy input followed by seed (11.3%). Figure 2 presents the shares of direct and indirect energy used in the production. Shares of direct energy and indirect energy inputs were 5.7% and 94.2% respectively.

**Table 3 Average amounts of inputs and output in cassava production**

| Quantity | Unit | Quantity per unit area (ha) |
|---|---|---|
| Inputs | | |
| Human labour | h | 104.4 |
| 2. Machinery | h | 40.1 |
| 3. Diesel fuel | L | 39.5 |
| 4. Fertilizers | | |
| a) Nitrogen (N) | kg | 252.1 |
| b) Phosphate (P205) | kg | 123.2 |
| c) Potassium (k20) | kg | 111.3 |
| 5. Chemicals | | |
| a) Herbicides | kg | 15.4 |
| b) Pesticides | kg | 18.4 |
| c) Fungicides | kg | 0.3 |
| 6. Seed | kg | 736.5 |
| Output | | |
| Cassava | kg ha$^{-1}$ | 32022.6 |

**Table 4 Average energy inputs used and output in cassava production per hectare (MJ ha$^{-1}$)**

| Quantity | Unit | Energy equivalent (MJha$^{-1}$) | Percentage (%) |
|---|---|---|---|
| Direct energy | | | |
| Human labour | H | 204.6 | 0.6 |
| Diesel | L | 1887.6 | 5.1 |
| Indirect energy | | | |
| Nitrogen | Kg | 16672.3 | 45.7 |
| Phosphate | Kg | 2148.8 | 5.9 |
| Potassium | Kg | 1527.5 | 4.2 |
| Herbicide | Kg | 3665.2 | 10 |
| Pesticide | Kg | 3663.6 | 10 |
| Fungicide | Kg | 73.1 | 0.2 |
| Machinery | H | 2515.7 | 6.9 |
| Seed | Kg | 4124.7 | 11.3 |
| Total energy input | MJ | 36482.8 | |
| Yield | Kg | 32022.6 | |
| Total energy output | MJ ha$^{-1}$ | 179326.8 | |
| Energy use efficiency | | 4.9 | |
| Energy productivity | kg MJ$^{-1}$ | 0.9 | |
| Specific energy | MJ kg$^{-1}$ | 1.1 | |

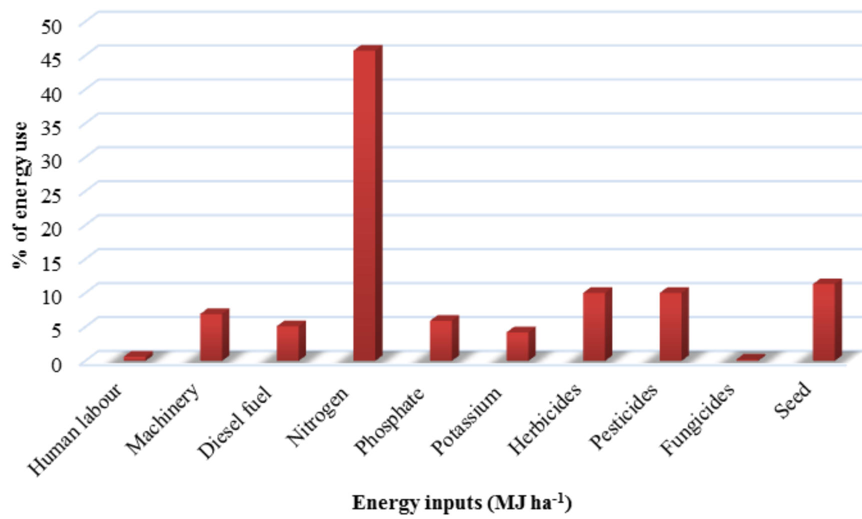


Figure 1 Energy use pattern in the cassava farms

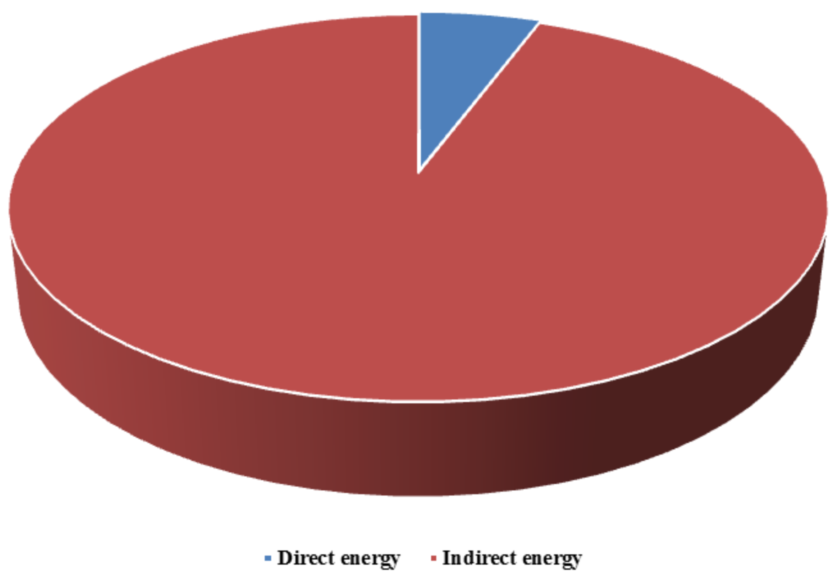


Figure 2 Percentage of total energy inputs in form of direct and indirect

A regression analysis result for Equation 8 is presented in Table 5. Results of regression analysis showed that each energy input had different effect on yield. Durbin-Watson test was done to test autocorrelation and results obtained were less than 2, implying the absence of autocorrelation at 5% significance level (Hossein et al., 2013). Human labor, fertilizer, cassava stem, machinery and fuel had positive effects on cassava yield except chemical energy input. This implies that the increase in human labor, fertilizer, cassava stem, machinery and fuel energies will increase the amount of output while 1% increase of chemical energy input will result in a decrease in energy output by 0.007%. Of all the variables, only the fertilizer, cassava stem and machinery variables were significant at 0.1%, 1% and 5% significant levels respectively. The R-squared was 0.93 and Durbin Watson statistic indicates no autocorrelation at 5% significant level. This means that each variable in the model was independent and an alteration in a particular variable had no influence on other variables. Also, variables contributed to cassava yield independently. Important variables that influenced cassava yield in this study were fertilizers, cassava stems, diesel and machinery.

**Table 5 Estimation results for parametric model and its coefficients**

| | $\alpha_i$ | t | P value |
|---|---|---|---|
| **Independent Variables** | | | |
| Human Labour | 0.017 | 1.879 | 0.066 |
| Chemical | -0.007 | -0.784 | 0.437 |
| Fertilizer | 0.259 | 7.794 | 5.97e-10 *** |
| Cassava Stem | 0.647 | 3.318 | 0.002 ** |
| Machinery | 0.664 | 2.398 | 0.22 * |
| Fuel | 0. 173 | 1.082 | 0.285 |
| $R^2$ | 0.93 | | |
| Durbin-Watson | 1.73 | | |

Note: ****significant at 0.1%; ** significant at 1%; *significant at 5%

## 4 Conclusions

Cobb-Douglas function was adopted to study energy use pattern and yield relationship in cassava production in Kwara State, Nigeria. Nitrogen fertilizer, seed, machinery and diesel had significant shares of the total energy used. Nitrogen fertilizer had the largest share of the total energy use. This can cause underground water pollution which would have harmful effects on man and the society. The total energy input in cassava production in this study was 36482.8 MJ ha$^{-1}$ while average output of cassava tubers was 32022.6 kg ha$^{-1}$. Energy use ratio, energy productivity and specific energy of the surveyed farms were 4.9, 0.9 kg MJ$^{-1}$ and 1.1 MJ kg$^{-1}$ respectively. Shares of the direct and indirect energy inputs were 5.7% and 94.2% respectively.

Results showed that all the coefficients (human labor, fertilizer, cassava stem, machinery and fuel) had positive effects on cassava yield except for chemical energy input. Fertilizer, cassava stem and machinery variables were significant at 0.1%, 1% and 5% significant levels respectively. R-squared was 0.93 and the Durbin Watson statistic indicates no autocorrelation at 5% significant level indicating that variables in the model were not dependent of each other and changes in the value of one variable had no significant effect on other variables. Also, all the variables contributed independently to cassava yield.

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