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National Academy of Agricultural Science (NAAS) Rating : 3. 03

Energy Inputs Flow Modeling and Sensitivity Analysis in Sesame Production in Jigawa State, Nigeria

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Abstract: *Data for this research was elicited through pre-tested questionnaire viz. 99 sesame farmers in Jigawa State of Nigeria via multi-stage sampling technique. Energy inputs flow modeling and sensitivity analysis in sesame production was studied using energy index models and traditional response function. Findings revealed that total energy inputs consumed in sesame production was 3944.01MJha^{-1}, with 79.94% of energy contributed by non-renewable energy inputs. However, energy ratio was found to be 3.34, implying that output energy obtained was 3.34 times greater than total input energy. Furthermore, results showed that farmers were operating within the rational stage of production. Findings suggest that reduction in agrochemical consumptions are important for energy saving and decreasing the environmental risk problem in the area. Also policies that prevent global warming, soil and water pollution should be enacted in order to ensure environmental friendly ecosystem.*

Keywords: *Energy; Flow; Sensitivity; Productivity; Sesame; Jigawa State; Nigeria.*

1. INTRODUCTION

Use of energy has increased in agriculture due to population explosion, desire for improved standards of living and limited supply of arable lands. High demand for increase food production led to considerable use of agro-chemical, agricultural machinery and other natural resources; but, intensive energy use causes public health and negative environmental impacts. Amount of energy used in agricultural production, processing and distribution needs to be adequate in order to feed the rising population and to meet other social and economic goals. Efficient use of energy resources in agriculture will reduce negative environmental impacts and destruction of natural resources, and improve sustainable agriculture as an economical production system. In other words, efficient use of energy would lead to increase agricultural production and productivity, economy growth, profitability, competitiveness, and sustainable agricultural development. Energy output-input analyses are intensively used to evaluate energy efficiency and environmental impacts, thus, determine how efficient energy inputs are utilized. This will aid in minimizing energy dissipation and also environmental damages due to the excessive use of energy inputs (inorganic fertilizer, pesticide, fuel, etc.). Reported literatures on energy expenditure in cultivation of different agricultural crops in Nigeria include; Millet production in semi-

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arid zone of Nigeria (Mohammed, 2012), plantain production in Nigeria (Jekayinfal *et al.*, 2012), maize production in Nigeria (Lawal *et al.*, 2014), pearl millet production in Niger State, Nigeria (Sadiq, 2015), maize production in Niger State, Nigeria (Sadiq and Isah, 2015). But there was no comprehensive study about economic analysis of energy use in sesame production in Nigeria; so this research aimed at determining total amount of input-output energy used in sesame production in Jigawa State of Nigeria. It also sought to evaluate efficiency of input energy consumption, making an economical analysis of sesame production, and also developing mathematical models to reveal the relationship between energy inputs and yield.

Furthermore, information on comparative use of different energy inputs is inadequate, and most of the producers do not have adequate knowledge on most efficient energy inputs. Consequently, it is neither possible to identify viable energy inputs and options in the production process nor plan for their conservation. Under these situations, an input–output energy analysis will provide planners and policy makers an opportunity to evaluate economic interactions of energy use. This information become imperative in order to make deductions on the efficiencies of energy inputs and suggestions on which energy sources or combinations need to be used and at what levels; thus, serve as data bank for any related study.

HYPOTHESES

A. Diagnostic tests (equation 5)

$H_0$1: Heteroskedasticity is not present

H_A1: Heteroskedasticity is present

$H_0$1: Error is normally distributed

H_A1: Error is not normally distributed

$H_0$1: Collinearity is not present

H_A1: Collinearity is present

B. Diagnostic tests (equation 6)

$H_0$2: Heteroskedasticity is not present

H_A2: Heteroskedasticity is present

$H_0$2: Error is normally distributed

H_A2: Error is not normally distributed

$H_0$2: Collinearity is not present

H_A2: Collinearity is present

C. Diagnostic tests (equation 7)

$H_0$3: Heteroskedasticity is not present

H_A3: Heteroskedasticity is present

$H_0$3: Error is normally distributed

H_A3: Error is not normally distributed

$H_0$3: Collinearity is not present

H_A3: Collinearity is present

2. RESEARCH METHODOLOGY

The economy of Jigawa State is largely characterized by informal sector activities with agriculture as the major economic activity. Most parts of the state lie within the Sudan Savannah with elements of Guinea Savannah in the southern part; enjoys vast fertile arable land to which almost all tropical crops could adapt. Multi stage sampling technique was used to generating a total sampling size of 99 respondents. In the first stage 3 LGAs *viz.* Taura, Malam-Madori and Maigatari were purposively selected due to high intensity of sesame cultivation. The second stage involved random selection of 3 villages from each selected LGA; and the last stage involved selection of 11 respondents from each village using simple random sampling technique, given a total sample size of 99. However, only 96 valid questionnaires were retrieved. Instrument for data collection was pre-tested questionnaire coupled

Table 1.1
Equivalents for various sources of energy

Items	*Unit*	*Equivalent MJ*	*Remarks*
Human Labour	Man-hour	1.96	
Improved seeds	Kg	25.5	Processed
Nitrogen	Kg	60.60	
P_2O_5	Kg	11.1	
K_2O	Kg	6.7	
Herbicides	Litre	238	
Manure	Kg	0.3	
Sesame product	Kg	25	

Table 1.2
Energy sources grouped under different categories of energy

Category energy	*Sources of energy*
Direct Energy	Human, Animal, Fuel wood, Agricultural waste, Petrol, Diesel, Kerosene, Electricity, etc.
Indirect Energy	Seeds, Farm yard manure, Chemicals, Fertilizer, Machinery, etc
Renewable Energy	Human, Animal, Fuel wood, Agricultural wastes, Seeds, Farm yard manure, etc
Non-Renewable	Petrol, Diesel, Electricity, Chemicals, Fertilizers, Machinery, etc
Commercial Energy	Petrol, Diesel, Electricity, Chemicals, Fertilizers, Machinery, Seeds, etc
Non-Commercial Energy	Human, Animal, Fuel wood, Agricultural wastes, Farm yard manure, etc.
Biological Energy	Diesel, Pesticides, Fertilizers, Machinery, Electricity, etc
Industrial Energy	Human, Seeds and H_2O for Irrigation

with interview schedule, which was administered on the respondents. Tool for data analysis were energy index and traditional response function (OLS).

3.2.1 Model specification

1. ***Energy standard equations:***

Standard equations were used to determine the following energy model index:

$$\text{Energy ratio} = \text{output energy } (\text{MJh}^{a-1}) / \text{Total input energy } (\text{MJh}^{a-1}) \quad ...(1)$$

$$\text{Energy productivity} = \text{Grain yield } (\text{kgha}^{-1}) / \text{Total input energy } (\text{MJh}^{a-1}) \quad ...(2)$$

$$\text{Net energy} = \text{Total output energy } (\text{MJh}^{a-1}) - \text{Total input energy } (\text{MJh}^{a-1}) \quad ...(3)$$

$$\text{Specific energy} = \text{Total input energy } (\text{MJh}^{a-1}) / \text{Grain yield } (\text{kgha}^{-1}) \quad ...(4)$$

2. ***Energy production function***

The analytical procedure employed was imposed energy production function analysis. This was used to obtain the parameters for the measurement of energy resource use efficiency of the maize farmers. Four functional forms were tried and the lead equation was selected based on economic, statistical and econometric criteria's. The function experimented with were linear, semi-log, exponential and double log.

The implicit function for out-inputs energy relationship is expressed as follows:

$$Y = f(X_1, X_2, X_3, X_4, X_4, X_5, X_6) \quad ...(5)$$

Where:

Y = Sesame output energy (MJ)

X_1 = Human labour energy (MJ)

X_2 = improved seeds energy (MJ)

X_3 = NPK fertilizer energy (MJ)

X_4 = SSP fertilizer energy (MJ)

X_5 = Manure energy (MJ)

X_6 = Herbicides energy (MJ)

Implicit function for energy forms (Direct and Indirect energy inputs) is expressed as follows:

$$Y = f(X_1, X_2) \quad ...(6)$$

Where:

Y = Sesame output (MJ)

X_1 = Direct energy (MJ)

X_2 = Indirect energy (MJ)

Implicit function for energy forms (Renewable and Non-renewable energy inputs) is expressed as follows:

$$Y = f(X_1, X_2) \quad ...(7)$$

Where:

Y = Sesame output (MJ)

X_1 = Renewable energy (MJ)

X_2 = Non-renewable energy (MJ)

The following functional forms were evaluated

(a) Linear function

$$Y = b_0 + b_1X_1 + b_2X_2 ... + b_nX_n + e_i \quad ...(8)$$

$$MPP = b$$

$$\text{Elasticity} = b * X/Y$$

(b) Semi–log function

$$Y = \log b_0 + b_1 logX_1 + b_2 logX_2 ... + b_n logX_n + e_i \quad ...(9)$$

$$MPP = b/X$$

$$\text{Elasticity} = b/Y$$

(c) The Cobb Douglas (double log) function

$$Log\ Y = \log b_0 + b_1 log\ X_1 + b_2 log\ X_2 \ldots + b_n log\ X_n + e_i \quad \ldots(10)$$

$$MPP = b^*Y/X$$

$$\text{Elasticity} = b$$

(d) Exponential function

$$Log\ Y = b_0 + b_1\ X_1 + b_2\ X_2 \ldots + b_n\ X_n + e_i \quad \ldots(11)$$

$$\text{MPP} = b^*X$$

$$\text{Elasticity} = b^*Y$$

Note:

b_0 = Intercept

$b_1 - b_n$ = Regression coefficients

3. RESULTS AND DISCUSSION

3.1 Energy Balance in Sesame Production

Amount of inputs and output energy utilized in sesame production are presented in Table 2. Results indicated an estimated 701.27MJha^{-1} of human labour was required in the study area; approximately 25.6 percent of total human labour was used in mound making (ridging); 25.3 percent in weeding; 10.4 percent in land clearing; 8.7 percent in herbicides spraying; 8.2 percent in threshing; 7.7 percent in fertilizer spreading; 5.6 percent in bagging; 4.3 percent in transportation and 4.2 percent in planting operations. The use of agro-chemical energy inputs *viz.* NPK fertilizer, SSP fertilizer and herbicides were 1677.69MJha^{-1}, 671.55MJha^{-1} and 316.54MJha^{-1}, respectively. However, organic fertilizer (manure) energy consumed in sesame production was 487.2MJha^{-1}, with 89.76MJha^{-1} consumed seed energy input. Moreover, the total energy consumption during the production period was observed to be 3944.01MJha^{-1}.

Furthermore, results on analytical investigation on input-output energy use in sesame production revealed that estimated total energy input consumed stood at 3892.91 MJh^{a-1} and total energy output was 13171.87 MJh^{a-1} (Table 2). Out of eight energy inputs consumed in sesame production process, nitrogen fertilizer (33.3%), human labour (18%) and SSP fertilizer (17.3%) energies respectively, had the highest shares. These findings indicate the necessity to increase the farmers and entities managers' knowledge-technical where withal about using the best and optimized energy inputs levels. Besides, using modern crop management practices in sesame production is a key factor for energy optimization, attending to other factors such as using energy saving materials (organic materials) as indirect energy, improving human labour knowledge, applying renewable energy resources are highly advised.

Findings of other studies reported total energy input of 2227.81 MJh^{a-1} in maize production in Niger State of Nigeria (Sadiq and Isah, 2015a; Sadiq and Isah, 2015b); 3291.28 MJha^{-1} in pearl millet production among small scale farmers of Niger State in Nigeria (Sadiq, 2015) 11420 MJha^{-1} in production of cotton in Bikaner district of Rajasthan in India (Verma *et al.*, 2015); 82193.24 MJha^{-1} in open grape production in East-Azerbaijan of Iran (Sattari-Yuzbashkandi *et al.*, 2014); 8936.68 GJha^{-1} in tomato production in Esfahan province of Iran (Rahbari *et al.*, 2013); 83809.8 MJha^{-1} in potato production in Esfahan province of Iran (Khoshnevisan *et al.*, 2013). Average yield value of sesame output was found to be 526.88 kgha^{-1}, which translate into 13172 MJha^{-1} of total output energy.

3.2 Shares of Energy Inputs in Sesame Production

The percentage distribution of the energy associated with the inputs is shown in Figure 1. It can be observed that the greatest part of total energy input was consumed by fertilizer (71.91%); followed by human labour (17.78%), then herbicides (8.03%) and seed (2.28%), respectively. Distribution of total fertilizers energy input was 32.88 percent Nitrogen, 6.02 percent Phosphorus, 3.63 percent Potassium, 17.03 percent SSP fertilizer and 12.35 percent manure (organic fertilizer). Excessive use of chemical fertilizers energy input in agriculture may create serious environmental consequences such as excess nitrogen deposit in the environment and receiving waters, poor water quality, carbon emissions and contamination of the food chain. Integrating legume into the crop rotation, application of composts,

Table 2
Amounts of inputs, output and their energy equivalents in sesame production

Inputs	*Quantity per hectare*	*Energy equivalent (MJ unit⁻¹)*	*Total energy equivalent per hectare (MJ^{ha-1})*	*Percentage (%)*
A. Inputs				
Human labour (manhrs)	357.79	1.96	701.27	17.78
Improved seeds (kg)	3.52	25.5	89.76	2.28
Nitrogen (kg)	21.40	60.60	1296.84	32.88
P_2O_5 (kg)	21.40	11.1	237.54	6.02
K_2O (kg)	21.39	6.7	143.31	3.63
SSP (kg)	60.50	11.1	671.55	17.03
Manure (kg)	1624	0.3	487.2	12.35
Herbicides (ltr)	1.33	238	316.54	8.03
Total energy input			*3944.01*	
B. Output				
Sesame seeds (kg)	526.88	25	13172	
Total energy output			*13172*	

Source: Field survey, 2015

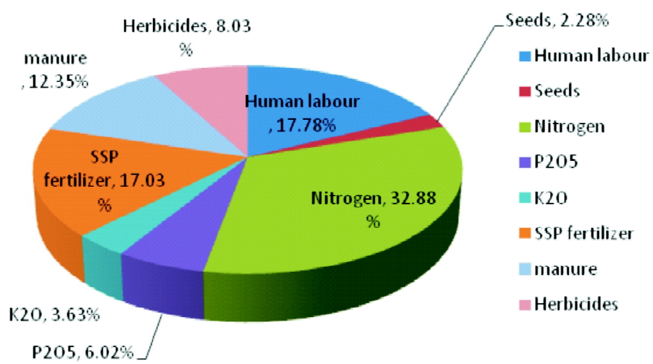

Figure 1: Shares of energy inputs in sesame production

chopped residues or other soil amendments may increases soil fertility in the medium term and so reduces the need for chemical fertilizer energy inputs. Moreover, applying a better management technique, employing

the conservation tillage methods or technological upgrade to substitute fossil fuels with renewable energy resources may be the pathways to minimize the fossil fuel usage and thus reduce its environmental footprints.

3.3 Energy Indices in Sesame Production

The energy indices *viz.* energy ratio, energy productivity, specific energy and net energy gain are given in Table 3. Energy ratio in sesame production was found to be 3.34; showing that output energy obtained was 3.34 times greater than total input energy, while specific energy was 7.49MJha^{-1}. Energy ratio and specific energy are integrative indices indicating the potential environmental impacts associated with the production of crops; also, these parameters can be used to determine the optimum intensity of land and crop management from an environmental point of view.

Table 3
Energy indices in sesame production

Items	Unit	Quantity
Energy ratio	–	3.34
Energy productivity	Kg MJ^{-1}	0.13
Specific energy	MJ Kg^{-1}	7.49
Net energy	MJ ha^{-1}	9227.99
Direct energy	MJ ha^{-1}	701.27 (17.78)
Indirect energy	MJ ha^{-1}	3242.74 (82.22)
Renewable energy	MJ ha^{-1}	791.03 (20.06)
Non-renewable energy	MJ ha^{-1}	3152.98 (79.94)

Source: Field survey, 2015

The input energy classification used in sesame production with respect to direct, indirect,

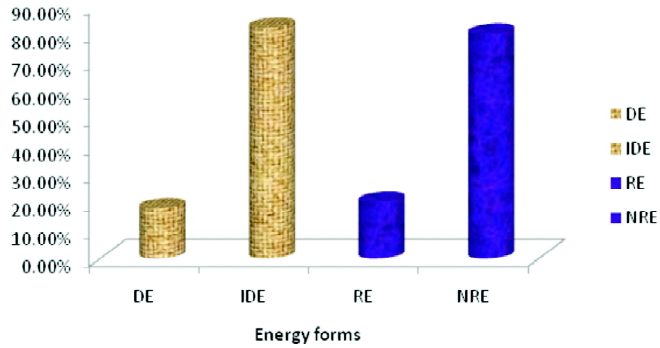

Figure 2: Distribution of energy forms in sesame production

renewable and non-renewable energy forms are shown in Table 3 and Figure 2. It's clear that, the ratios of direct and indirect energy forms; renewable and non-renewable energy forms are fairly different from each other. The ratio of indirect and non-renewable energy forms are very high, indicating that sesame production in the study area depends mostly on agrochemicals.

3.4 Sensitivity Analysis of Energy Inputs on Sesame Production

The influence of energy inputs on output was determined with the aid of production function analysis. On the basis of *a priori* expectation, the statistical significance of the coefficients and the coefficient of multiple determination the double logarithm functional form was chosen as the best fit for equation 5 (Table 4). Results reveal that almost all energy inputs were positively related to the output, except SSP fertilizer and biocide (herbicides). R^2 value indicates that approximately 84 percent of variations in sesame output were explained by the explanatory variables included in the model; implies all the included exogenous variables in the model contributed to sesame output by 84 percent.

Moreover, human labour and seed energies respectively, significantly influence sesame output at 1 percent level, while NPK fertilizer, SSP fertilizer, manure and herbicides energies respectively, significantly influence sesame output at 5 percent probability level. Since the coefficient of the double log equation is the elasticity, the following can be inferred: a unit increase in the level of human labour, seed, NPK fertilizer, SSP fertilizer, manure and biocide (herbicides) energies respectively, will result to 0.55, 0.54, 0.16, –0.21, 0.13 and –0.20 percent changes in sesame output respectively; with respect to estimated parameters, 1 percent increase in energy consumption from human labour, seed, NPK fertilizer, SSP fertilizer, manure and biocide energies respectively, will lead to 0.55%, 0.54%, 0.16%, –0.21%,0.13% and –0.20% changes in sesame output, respectively.

The summation value of elasticity coefficients termed RTS was 0.98, implying decreasing returns to scale. This suggests that sesame producers in the study area are within the economic relevance point of production, thus, they should be judicious in resources allocation in order to optimize their output.

Table 4
Regression estimates of input-output energy analysis

Variable	*Coefficient*	*SE*	*t-stat*	*Mean*	*MPP (MJ)*	*MPP (Kg)*
Constant	3.917	0.938	4.17***			
H. Labour	0.553	0.118	4.69***	1002.89	11.64	0.47
Seeds	0.539	0.088	6.14***	143.84	79.12	3.17
NPK fertilizer	0.158	0.063	2.50**	2572.39	1.297	0.05
SSP fertilizer	–0.206	0.082	–2.5**	965.47	–4.04	-0.18
Manure	0.132	0.056	2.3**	689.97	4.04	0.16
Herbicides	–0.196	0.078	–2.5**	447.49	–9.25	-0.37
R2	0.84					
Adjusted R2	0.83					
F-stat	78.02***					

Source: Field survey, 2015

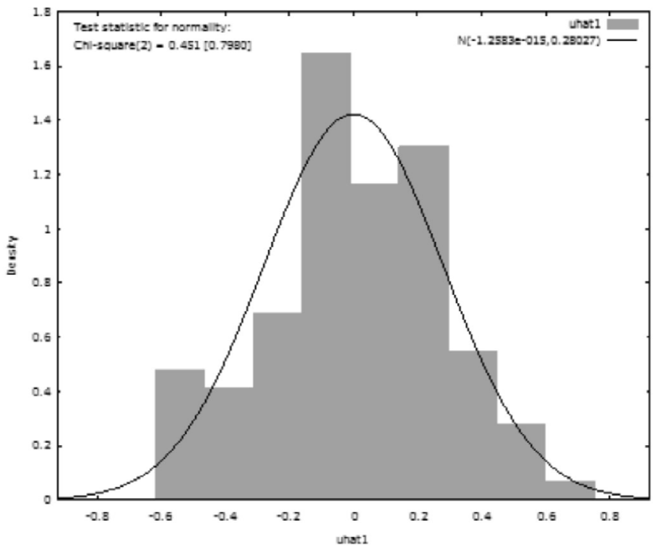

Figure 3: Normally test for residuals distribution of Equation 5

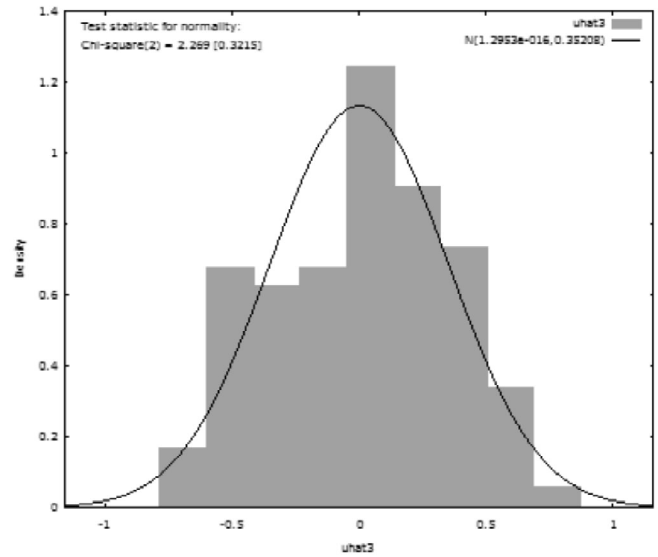

Figure 3: Normally test for residuals distribution of Equation 6

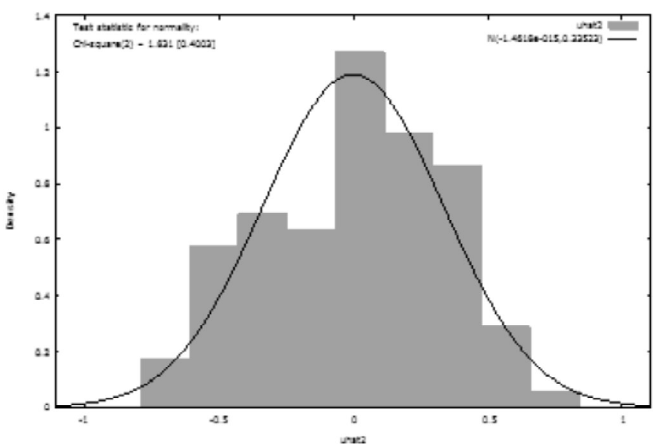

Figure 3: Normally test for residuals distribution of Equation 7

MPP values reveal that the farmers were more efficient in the use of seed energy than other energy resources. This implies that if additional seed energy (MJ) was available, it would lead to an increase in sesame output by 3.17kg among the farmers. This means that the farmers are more technically efficient in the use of seed energy. Of all the energy resources used, biocide (herbicides) had the least MPP (–0.37kg). This implies inefficiency in the use of available biocide (herbicides). However, additional use of 1 MJ from each of the human labour, seed, NPK fertilizer and manure energies respectively, would lead to an additional increase in sesame output by 0.47kg, 3.17kg, 0.05kg and 0.16kg, respectively. In other words, there exist high potential for output increase by additional use of these inputs for sesame production in the study area.

On the other hand, MPP values of SSP fertilizer and biocide (herbicides) energies respectively, were negative, meaning use of these inputs were high in sesame production, resulting in energy dissipation as well as imposing negative effects to environment and human health. The results of sensitivity analysis reveals which variables should be identified and measured carefully in assessing the state of environmental system, and which environmental factors should be managed preferentially. Within this framework, sensitivity analysis of energy inputs is important for improving energy use efficiency and lowering the environmental footprints of energy consumption.

For investigating the relationship between energy forms (*i.e.* direct, indirect, renewable and non-renewable) and the output of sesame were fitted into four functional forms. Double logarithm gave the best fit for both equations, because it satisfies the economic, statistical and econometric criteria's, respectively. The R^2 value of equation development between direct and indirect energies, respectively against sesame output was 74 percent, implying that 74 percent variation in sesame output was influenced by the explanatory variables included in the model, while the R^2 value of equation development between renewable and non-renewable energies, respectively against sesame output was 76 percent, indicating that 76 percent variation in sesame output was determined by the independent variables included in the model.

Table 6
Regression estimates of energy forms

Variable	*Coefficient*	*SE*	*t-stat*	*Mean*	*MPP (MJ)*	*MPP (Kg)*
Constant	–1.006	0.786	–1.28^{NS}			
Direct	1.094	0.097	11.33***	1002.89	23.03	0.92
Indirect	0.388	0.108	3.58***	4819.15	1.70	0.07
R^2	0.737					
Adjusted R^2	0.731					
F-stat	130.03***					
Constant	–0.658	0.786	–0.882^{NS}			
Renewable	1.129	0.097	12.66***	1146.72	20.79	0.83
Non-renewable	0.303	0.108	2.911***	4675.32	1.37	0.06
R^2	0.761					
Adjusted R^2	0.756					
F-stat	148.2***					

Source: Field survey, 2015

The parameters results of model development between direct and indirect energies indicated that both energy forms had the *apriori* expectation and their effects were statistically significant, with elasticity values of 1.09 and 0.39 for direct and indirect energy inputs, respectively. These implies that a unit increase in direct and indirect energy inputs respectively, will lead to 1.09 and 0.39 increases in sesame output respectively. However, parameters of model development between renewable and non-renewable energies showed that both energy forms were positive and significant at 1 percent probability levels. Also, the elasticity of renewable energy was higher than that of non-renewable energy, meaning that 1 percent increase in use of renewable energy inputs will lead to 1.13 percent increase in sesame output, while 1 percent increase in non-renewable resources increases will increase the output by 0.3 percent. Moreover, MPP values of direct and indirect; renewable and non-renewable energy forms were 0.92, 0.07, 0.83 and 0.06, respectively. However, sensitivity analysis of direct and indirect; renewable and non-renewable energy forms indicates that additional use of 1 MJ of the aforementioned energy forms will lead to additional increase in output by 0.92 kg, 0.07 kg, 0.83kg and 0.06kg, respectively. These results may be due to the fact that renewable energy forms (human labour) was used intensively by most farmers because it is almost free, i.e cheap and readily available, thus making its share high; while non-renewable energy forms especially agro-chemicals were partially used by the farmers due to their poor capital base, thus, rendering its share very low.

Additional use of non-renewable energy sources to boost sesame productions in the study area with low levels of technological knowledge not only results in environmental deterioration, but also confronts them with the dilemma of a rapid rate of depletion of energetic resources; while, renewable energy sources can be used indefinitely with minimal environmental impacts associated with their production and use. Development of renewable energy usage technologies such as improved integrated pest management technique and utilization of alternative sources of energy such as organic fertilizers (compost, manure, etc.) are the best pathways to substitute the non-renewable energy forms with renewable resources and to reduce their environmental footprints. Furthermore , propagating the benefits of new farm technology based primarily on high-yielding variety of sesame seeds are alright, but the alternatives of ensuring continuation of traditional varieties with matching results should not be ignored; authors' discovered traditional varieties of sesame seeds almost extinct, which they feel is going to pose serious problems for future. Therefore, it is the opinion of the authors' that, while making advances in agricultural

Table 7a
Diagnostic test results (Heteroskedasticity and Normality tests)

Test	Test-stat	P-value	Decision (H0)
Equation 1			
1. Heteroskedasticity			
Breusch-Pegan	3.93487	0.68549	Accepted
White's	20.3238	0.816895	Accepted
Koenker	5.19512	0.519043	Accepted
2. Normality (Chi^2)	0.451273	0.798008	Accepted
Equation 2			
3. Heteroskedasticity			
Breusch-Pegan	0.0891602	0.956399	Accepted
White's	1.25363	0.93963	Accepted
Koenker	0.141826	0.931543	Accepted
4. Normality (Chi^2)	2.26939	0.32152	Accepted
Equation 3			
5. Heteroskedasticity			
Breusch-Pegan	0.236389	0.888523	Accepted
White's	0.993907	0.963056	Accepted
Koenker	0.353844	0.837845	Accepted
6. Normality (Chi^2)	1.83125	0.400267	Accepted

Source: Computer print-out

technologies, aspects of future stability should not be overlooked, and while ensuring reasonable agricultural prosperity at present, we should not preside over the feature gloom.

HYPOTHESES

A. Diagnostic Test (equation 5)

1. ***Heteroskedasticity test:*** Assumption of constant variance (homoskedasticity) of residual hold, because the Test-statistics were non-significant ($P > 0.10$). Therefore, the null hypothesis of heteroskedasticity not present is accepted while the alternative is rejected.
2. ***Normality test:*** Assumption of normality in distribution of residuals holds, because the chi^2 value was non-significant. Therefore the null hypothesis of error is normally distributed is accepted while the alternative is rejected.

Table 7b
Diagnostic Test Results (Multi-collinearity)

Variables	Values > 10.0 may indicate a collinearity problem
1. *Equation 1*	
Land	3.316
Seed	3.990
NPK fertilizer	1.680
SSP fertilizer	1.115
Manure	1.105
Herbicides	1.204
2. *Equation 2*	
DE	1.407
IDE	1.407
3. *Equation 3*	
RE	1.419
IRE	1.419

Source: Field survey, 2015

3. ***Collinearity:*** Assumption of non-multicollinarity between independent variables hold, because the variables value are less than VIF value (Values > 10.0 may indicate a collinearity problem)

B. Diagnostic Test (equation 6)

4. ***Heteroskedasticity test:*** Assumption of constant variance (homoskedasticity) of residual hold, because the Test-statistics were non-significant ($P > 0.10$). Therefore, the null hypothesis of heteroskedasticity not present is accepted while the alternative is rejected.
5. ***Normality test:*** Assumption of normality in distribution of residuals holds, because the chi^2 value was non-significant. Therefore the null hypothesis of error is normally distributed is accepted while the alternative is rejected.
6. ***Collinearity:*** Assumption of non-multicollinarity between independent variables hold, because the variables value are less than VIF value (Values > 10.0 may indicate a collinearity problem)

C. Diagnostic Test (equation 7)

7. ***Heteroskedasticity test:*** Assumption of constant variance (homoskedasticity) of residual hold, because the Test-statistics were non-significant ($P > 0.10$). Therefore, the null hypothesis of heteroskedasticity not present is accepted while the alternative is rejected.
8. ***Normality test:*** Assumption of normality in distribution of residuals holds, because the chi^2 value was non-significant. Therefore the null hypothesis of error is normally distributed is accepted while the alternative is rejected.
9. ***Collinearity:*** Assumption of non-multicollinarity between independent variables hold, because the variables value are less than VIF value (Values > 10.0 may indicate a collinearity problem)

CONCLUSION AND RECOMMENDATIONS

The results revealed that energy inputs *viz.* human labour, seeds, NPK fertilizer and manure had positive effects on sesame output in the study area. In other words, there exist high potential of output increase by additional use of these inputs in sesame production; while the use of SSP fertilizer and herbicides energy inputs were inconsistent with output, implying their use been high, thus, resulting in energy dissipation as well as imposing negative effects on environment and human health. Moreover, results indicated that sesame production in the study area showed high sensitivity to non-renewable energy sources which may result in both environmental deterioration and rapid rate of depletion of these energetic resources. Therefore, input mix that shapes technology should be designed carefully; seeds, fertilizers and pesticides have to be combined in such a way as to meet the present challenges and also ensure stability in the future. Since agro-chemicals pose a far more serious problem; these can become big health hazards unless used properly and in desirable quantities. As such greater caution should be exercised in this regard keeping in view the socioeconomic conditions of the study area. For arriving at optimal combination, farm education and management should play an important role.

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