Journal of Energy Research and Environmental Technology (JERET)
Print ISSN: 2394-1561; Online ISSN: 2394-157X; Volume 2, Number 5; April-June, 2015; pp. 343-348

http://www.krishisanskriti.org/jeret.html

Efficient Utilization of Renewable and Non-renewable Bioresource Inputs Energy-use in Pearl Millet Production Among Small Scale Farmers in Niger State, Nigeria and Potentials of Energy Savings

Sadiq, Mohammed Sanusi

PhD Scholar, Department of Agricultural Economics, Swami Keshwanand Rajasthan Agricultural University, Bikaner-334006, India
E-mail: sadiqsanusi30@gmail.com

Abstract—*The research conducts an in-depth investigation on efficient utilization of renewable and non-renewable energy in pearl millet production among small scale farmers in Niger state, Nigeria and potentials of energy savings. The study employed multi-stage sampling technique to draw a total sample size of 160 respondents from the study area. Both interview schedule and pre-tested questionnaire were used to elicit information for the study from the respondents. Data were collected during the 2014 cropping season. Energy production function analyses which incorporate the conventional neoclassical test of energy-technical and energy-economic efficiencies, and energy index models were used to analyze the data collected. Results showed that Total inputs energy MJ in pearl millet production was 3291.28MJha^{-1}, with 70.2% of input energy contributed by renewable energy inputs. However, energy ratio was 3.69 in the production systems. Furthermore, findings revealed that farmers were inefficient in the use of all the energy inputs, with energy inputs such as nitrogen MJ, P_2O_5 MJ, K_2O MJ, free labour MJ and herbicides MJ been over-utilized while energy input from seed was under-utilized. Results 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 thereby creating environmental friendly ecosystem.*

Keywords: *Efficiency; Renewable energy inputs; Non-renewable energy inputs; Pearl millet; Niger state; Nigeria*

1. INTRODUCTION

The age old necessities of life are food, clothing and shelter. The 20th and 21st has century dramatized and devised a fourth one known as energy. Energy starvation of the technological complex that maintains modern society may soon be a crucial problem as feeding the world's hungry. Therefore, energy starvation could well precipitate more widespread food starvation. Solutions for energy crisis are strongly dependent on the technology of how energy is utilized. However, to make a physical change in the world it is necessary to use four resources: energy, space and time. How well a tasked is been performed can be measured in terms of the amount of fuel consumed, the mass of material used, the space occupied, labour hour required to accomplish a task and the ingenuity with which these resources are utilized. Squandering of irreplaceable energy sources, wastes of materials, or large expenditures of of space and time should not be tolerated if the necessities of life are to be provided for all. Technology addresses itself to the efficient utilization of these four ingredients of physical change. The era of cheap energy is now coming to an end and the populace will necessarily become energy conservation conscious because of the rising cost for energy and the dire consequences of placing additional stresses on our biosphere, already showing serious strain signs. The introduction of high yielding varieties of major crops in sixties paved the way for important technological changes that led to unprecedented rise in the crop yield and land productivity in many parts of the country. These new production technologies made use of large quantity of inputs such as fertilizers, chemicals, plant protections, diesels, farm machineries, fuel, electricity, etc. The application of these inputs demands more and more use of energy in the form of human, animal and machinery. With improved rural transportation system, the rural unskilled labour has become more mobile thereby making agricultural labour supply elastic. Therefore, since the energy scenario of crop production has changed with the introduction of modern inputs, it become imperative to study the energy utilization patterns analytically and suggest what is likely to happen in the future on energy front. Efficient use of energies helps to achieve increased productivity and contributes to the economy, profitability and competitiveness of agriculture sustainability in rural areas [4]. Furthermore, in order to meet the ever increasing demand for food production, energy use in agriculture production has become more intensive which even brought some important human health and environment issues forcing humans to make more efficient use of inputs to maintain a sustainable agriculture production [5].

2. THEORETICAL FRAMEWORK OF ENERGY FUNCTION IN EFFICIENCY STUDIES

The modeling and estimation of energy efficiency of a firm relative to other firms or the 'best' practice in an industry has become an important area of economic study. Energy productivity is generally measured in terms of the efficiency with which energy inputs, such as fertilizer MJ, labour MJ, animal MJ, machine MJ, seed MJ, herbicides MJ, petrol MJ, diesel MJ, electricity MJ, etc are converted to output within the production process. There are two measures of energy productivity namely, partial energy input productivity and total energy input productivity. Partial energy input productivity is measured as the ratio of output to a single input. The ratio of output to all inputs combined is the total energy input productivity. Generally, two approaches are used in measuring total energy input productivity. These are the growth accounting or index number approach and the econometric or parametric method. The econometric method is based on an econometric estimation of the energy function. In this study, the energy function is used to measure the productivity (or energy use efficiency of millet farmers). From the imposed energy function, the conventional neoclassical test of economic efficiency of energy was derived. The rule of this test is that the shape of the imposed energy function (MEP) should be equal to the inverse ratio of energy input price to output price at the profit maximization point. This is given as:

MEPxi= Pxi/Py

Where:

Pxi = unit price MJ^{-1} input used

Py = output price MJ^{-1}

MEP = marginal energy product of resource input used

MEP x Py = MVEP

MVEP/UEFC = r

Where:

MVEP = marginal value energy product

UEFC = unit energy cost

r = allocation index

In an attempt to substitute the efficiency hypothesis, focus is centered on the estimated value of r and its closeness to unity. Efficiency is attained if MVEP = UEFC.

3. RESEARCH METHODOLOGY

The study was conducted in Niger state, Nigeria. Multi-stage sampling was used to select a total of 160 respondents from two local government areas. Pre-tested questionnaires were used to elicit informations from the farmers. Data analysis was done using energy index models and traditional response function (OLS).

Table 1.1: Sampling frame of millet farmers

Agro-zone	LGAs	Respondents
Kontagora	Rijau	80
	K/gora	80
Total	2	160

Source: Field survey, 2014

Table1.2: 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

Table 1.3: Equivalents for various sources of energy

Particulars	Units	Equivalent energy, MJ
Adult man	Man-hour	1.96
Women	Woman-hour	1.57
Child	Child-hour	0.98
Nitrogen	Kg	60.60
P_2O_5	Kg	11.1
K_2O	Kg	6.7
Herbicides	Litre	120
Manure	Kg	18.0
Insecticides	Litre	120
Improved seed	Kg	15.2
Millet product	Kg (Dry mass)	14.7

3.2.1 Model specification

1. Energy standard equations: Standard equations were used to determine the following energy model index:

Energy ratio = output energy ($MJha^{-1}$)/Total input energy ($MJha^{-1}$) ………… ………. (1)

Energy productivity = Grain yield ($kgha^{-1}$)/ Total input energy ($MJha^{-1}$) ……………... (2)

Net energy = Total output energy ($MJha^{-1}$) – Total input energy ($MJha^{-1}$) …… ………..(3)

Specific energy = Total input energy ($MJha^{-1}$)/ Grain yield ($kgha^{-1}$) …………… ……… (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 millet farmers. Four functional forms were tried and the lead equation was chosen based on economic, econometric and statistical criteria including signs and magnitudes of the coefficients, the magnitude of R^2, T-statistics, F-statistics. The function experimented were linear, semi log, double log and exponential. The implicit function can be presented by the following equation:

Y=f(X1,X2,X3,X4,X4,X5,X6,X7) ………… …... (4)

Where:

Y = Output of Millet (MJ)

X_1 = Nitrogen (MJ)

X_2 = P_2O_5 (MJ)

X_3 = K_2O (MJ)

X_4 = Free labour used (MJ)

X_5 = Paid labour used (MJ)

X_6 = Improved seeds (MJ)

X_7 = Herbicides (MJ)

Determining technical efficiency of energy resource use

The elasticity of energy production which is the percentage change in output as a ratio of a percentage change in input was used to calculate the rate of return to scale which is a measure of a firm's success in producing maximum output from a set of input.

EEP = MEP/AEP

Where:

EP = elasticity of production

MEP = marginal physical product

AEP = average physical product

If

EEP =1: constant return to scale

EEP < 1: decreasing return to scale

EEP > 1: increasing return to scale

Determining the economic efficiency of energy resource use

The following ratio was used to estimate the relative efficiency of energy resource use (r)

r = MVEP/UEFC

Where:

UEFC = unit cost of a particular energy resource

MVEP = value added to millet output due to the use of an additional unit of MJ input, calculated by multiplying the MEP by the unit price of MJ output . i.e. MEPxi x Py

Decision rule

If r = 1, energy resource is efficiently utilized,

if r > 1, energy resource is underutilized, while,

if r < 1, energy resource is over utilized.

Economic optimum takes place where MVEP = UEFC. If r is not equal to 1, it suggests that an energy resource was not efficiently utilized. Adjustments could therefore, be made in the quantity of energy inputs used and costs in the energy production process to restore r = 1 and the model is given as follows:

Divergence % = (1-1/ri) x100 or [(ri-1)/ri] x100

4. RESULTS AND DISCUSSION

4.1 Source-wise energy consumption

Table 2 revealed source-wise energy consumed in millet production in the studied area. The total input energy requirement for producing millet crops was 3291.28 $MJha^{-1}$ with indirect energy used contributing the highest share in total energy input consumed (2933.52$MJha^{-1}$). Among the different energy sources manure was the highest energy consumed, with an average of 103$kgha^{-1}$ used. It is a common belief that increase in organic fertilizer use will lead to an increase in yield. Therefore, because of the high organic fertilizer used in the production, it account for the highest value in total energy input used in millet production (1854$MJha^{-1}$). However, other inputs applied in the growing process, and percentage of each input to the total energy inputs are given in the table.

Table 2: Source-wise energy consumption in millet production

Variables	Quantity units ha^{-1}	Total $MJha^{-1}$	% of Total energy
a. Inputs			
Direct energy			
Adult man labour	146.56 manhours	287.26	8.7
Adult woman labour	18 manhours	28.26	0.9
Child labour	44 manhours	42.24	1.3
Sub-total		357.76	10.9
Indirect energy			
Seeds	6.5kg	98.8	3
Nitrogen	8.3kg	502.98	15.3
Phosphorus (P_2O_5)	8.3kg	92.13	2.8
Potassium (K_2O)	8.3kg	55.61	1.7
Herbicides	2.3litre	1854	56.3
Manure	103kg	276	8.4
Insecticides	0.45litre	54	1.6
Sub-total		2933.51	89.1
Total input energy ($MJha^{-1}$)		3291.28	100
b. Output			
Millet	825kg	12127.50	
Total energy output ($MJha^{-1}$)		12127.50	

Source: Field survey, 2014

4.2 Yield and energy requirement in different form for millet production

Table 3 shows the energy requirement in different forms for millet production Agro-ecosystems. The energy productivity, energy ratio, specific energy, net energy and Agrochemical energy ratio of maize production in the study area were identified. Energy ratio in millet production was 3.69; therefore, raising the crop yield and decreasing energy inputs consumption the energy ratio can be increased. This findings is greater than the amount recorded for cereals production by Canakci [1] in Turkey (3.66) and Lorzadeh [3] in Iran(1.86), respectively. This high energy ratio implies efficient use of energy in millet production. Energy productivity and specific energy in millet production systems were 0.25KgMJ^{-1} and 3.99MJKg^{-1} respectively. This means that produced millet grain per unit consumed input energy unit of 0.13kgMJ^{-1}, or in other word, in millet production, 3.99MJ energy was used for producing one kg of grain yield. Also, Net energy per hectare for millet production was 8836.22MJha^{-1}. Furthermore, the agrochemical energy ratio in millet production was 30 percent which implies relatively low energy input consumed from agrochemical inputs in the production. However, distributions of other inputs used in the production according to the industrial and biological; renewable and non-renewable; and, commercial and non-commercial were also identified. The total biological energy input consumed was 86.13%, while industrial energy accounted for 13.87%. Moreover, several researchers reported the ratio of industrial energy to be greater than biological energy consumption in crops production [6, 2, 3]. In modern crop production systems large amount of industrial energy has been replaced with biological energy, therefore energy use has been reduced in response to use low use of agrochemical input with high energy cost and effective use of input energy.

Table 3: Yield and energy requirement in different form for millet production

Items	Unit	Quantity
Yield	Kgha^{-1}	825
Total input energy	MJha^{-1}	3291.28
Output energy	MJha^{-1}	12127.50
Energy ratio		3.69
Specific energy	MJkg^{-1}	3.99
Energy productivity	KgMJ^{-1}	0.25
Net energy	MJha^{-1}	8836.22
Agro-chemical energy ratio	%	30
Industrial energy	MJha^{-1}	456.56 (13.87)
Biological energy	MJha^{-1}	2834.72 (86.13)
Renewable energy	MJha^{-1}	2310.56 (70.2)
Non-renewable energy	MJha^{-1}	980.72 (29.8)
Commercial energy	MJha^{-1}	1079.52
Non-commercial energy	MJha^{-1}	2211.76

Source: Field survey, 2014

4.3 Energy inputs and millet output relationship

The functional relationship between different energy inputs and maize output was shown in Table 4a. The influence of energy inputs on maize output was determined with the aid of energy production function analysis. On the basis of *a priori* expectation, the statistical significance of the coefficients and the coefficient of determination, the semi logarithm functional form was chosen as the lead equation. The result reveals that almost all the energy inputs were positively related to the output. The value of the R^2 reveals that approximately 62% of the variations in millet output in the area were explained by the independent energy input variables included in the model, while 38% was due to systematic error which were unexplained by the energy function or random disturbance in the model. The F-ratio of 25.95 was significant at 1 percent level, meaning that the explanatory variables included in the model have strong explanatory power. The F-ratio is a measure of joint significance of all explanatory variables in the population. All energy inputs significantly influenced millet output at different probability level, except paid labour. Furthermore, Nitrogen and seed MJ were significant at 1 percent while Phosphorus (P_2O_5), potassium (K_2O), free labour and herbicides MJ respectively, significantly influenced millet output at 10 percent level. Paid labour MJ was not significant; and as such need no further discussion. The MJ elasticity coefficient for constant was 76.79, which implies that at zero commitment of MJ inputs, output will increase by 76.79 percent. Therefore, it can be inferred that a unit MJ increase in Nitrogen, P_2O_5, K_2O, free labour, seed and herbicides will lead to -0.079, -0.141, 0.141, 0.089, 0.29 and 0.028 percent changes in millet output, respectively. The inputs with positive MJ coefficients imply an increase in millet output, while negative coefficient MJ implies a decrease in millet output. Except nitrogen and P_2O_5 MJ which was in the irrational energy production stage III (deminishing), all other significant MJ inputs were within the rational energy production stage (stage II) which is referred to as economic stratum in production theory. The sum of the value of MJ coefficients was 0.65 and implies decreasing returns to scale (4b). This suggests that millet farmers in the study area can increase their output by employing less of all the energy inputs. Measure of technical energy efficiency of energy resources used such as Average Energy Product (AEP), Marginal Energy Product (MEP), and Marginal Energy Value Product (MVEP) and Unit Energy Factor Cost (UEFC) were derived (Table 4c-d). The values of the MEP show that the farmers were more efficient in the use of K_2O MJ than the other resources. This suggests that if additional MJ were available, it would lead to an increase in millet output by 17.91 among the farmers, thus meaning that farmers were more technically energy efficient in the use of K_2O MJ. Of all the energy resources used, P_2O_5 had the least MEP (-10.81 MJ). This shows inefficiency in the use of available P_2O_5. Given the level of technology and prices of both energy inputs and outputs, efficiency of energy resource use was further ascertained by equating the MVEP to the productive UEFC of resources. A resource is said to be energy optimally allocated if there is no significant difference between the MVEP and UEFC that is, if the ratio of MVEP to UEFC =1. Table 4c reveals that the ratios of the MVEP to the UEFC were less than unity (1) for all the energy input except seed MJ. This implies that nitrogen MJ, P_2O_5 MJ, K_2O MJ, free labour MJ and herbicides MJ were over-utilized, while seed MJ was under-utilized. Therefore, millet output was likely to increase and hence revenue if less of these inputs MJ (nitrogen, P_2O_5, K_2O, free labour and herbicides) and more of seed MJ had been utilized. The adjustment in the MVEPs for optimal energy resource use (% divergence) indicates that for optimum allocation of energy resources more than 6% increase in K_2O was required, while approximately 45% increase in free labour was needed. Similarly, over 36% and 27% increase in seed MJ and herbicides MJ respectively are needed. Nitrogen MJ and P_2O_5 MJ were over-utilized, and required approximately 11.1% and 6.75% reduction for optimal energy use in millet production.

Table 4a: Functional relationship between output and different energy inputs in millet production

Variables	Coefficient	Standard error	t-statistics
Nitrogen (MJ)	-0.079	0.02646	2.98***
P_2O_5 (MJ)	-0.141	0.0727	1.94*
K_2O (MJ)	0.141	0.0722	1.94*
Free labour (MJ)	0.0891	0.0464	1.92*
Paid labour (MJ)	0.0072	0.005611	1.29NS
Seed (MJ)	0.292	0.085	3.44***
Herbicides (MJ)	0.0498	0.0276	1.80*
Constant	76.785	36.564	2.10**
R^2	0.62		
R^2 adjusted	0.60		
F- statistics	25.95***		

Source: Field survey, 2014

Table 4b: Elasticity of energy production function

Variables	Coefficients
Constant	76.79
Nitrogen (MJ)	-0.079
P_2O_5 (MJ)	-0.141
K_2O (MJ)	0.141
Free labour (MJ)	0.089
Paid labour (MJ)	0.007
Seed (MJ)	0.292
Herbicides (MJ)	0.028
RTS	0.34

Source: Field survey, 2014

Table 4c: Technical energy efficiency parameters

Variables	AEP	MEP
Nitrogen (MJ)	7.09	-0.56
P_2O_5 (MJ)	76.67	-10.81
K_2O (MJ)	127.02	17.91
Free labour (MJ)	61.06	5.44
Paid labour (MJ)	88.89	0.64
Seeds (MJ)	26.92	7.86
Herbicides (MJ)	21.69	1.08

Source: Field survey, 2014

Table 4d: Allocative energy efficiency estimates

Variables	MEP	MVEP	UEFC	AEEI (r)	% Divergence
Nitrogen (MJ)	-0.56	2.29	24.75	-0.09	-11.1
P_2O_5 (MJ)	-10.81	44.11	135.14	-0.326	-6.75
K_2O (MJ)	17.91	73.07	223.88	0.326	6.75
Free labour (MJ)	5.44	22.20	76.53	0.29	44.85
Seed (MJ)	7.86	31.20	19.74	1.58	36.71
Herbicides (MJ)	1.08	4.41	10	0.44	27.27

Source: Field survey, 2014

5. CONCLUSION AND RECOMMENDATION

This research investigated efficient utilization of renewable and non-renewable energy in millet production in Niger state, Nigeria. The total energy consumed in millet production was 3291.28MJha^{-1}, with energy input from organic fertilizer yielding the highest share (56.3%) of total input energy. However, 86.13% of total energy input used in millet production was biological energy, while the contribution of industrial energy was 13.87%. Findings revealed that millet farmers were technical inefficient in the use of energy input resources. The inefficiency of these farmers may be directly or indirectly linked to the inadequate knowledge on energy conservation consciousness; rising cost for energy, dire consequences in placing additional stresses on our biosphere, and energy scenario pattern in crop production. Results suggest that reduction in agrochemical consumptions are important for energy saving and decreasing the environmental risk problem in the area. Therefore, excessive application of inorganic fertilizer would result in increased energy consumption in production systems; inefficient energy use, thus, causing environmental challenges, including global warming, soil and water pollution thereby affecting human health. This trend indicates that environmental challenges will worsen in the near future if there is absence of managerial consideration in inorganic fertilizer application pattern in these agro-ecosystems. The research inferred that improvement in energy use efficiency among these farmers is the responsibility of the individual farmers, government and research institutions.

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