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A source-wise and operation-wise energy use analysis for wheat production, Saurashtra region of Gujarat, India

Jaya D Varu, PM Chauhan, Gaurav Mishra and Sameer Vohra

Abstract
This study aims at finding the input–output energy use and the relationship between energy input levels on wheat yield in Saurashtra region of Gujarat, India. Besides, the energy analysis was carried out based on different farm operations. Data were collected from 605 farmers (small marginal farmers 287, medium marginal farmers 288, and large marginal farmers 30) using face to face questionnaire method. The source wise total energy input consumption was 25327.58, 32043.23 and 55549.24 MJ for small, medium and large marginal wheat farmers; in which Irrigation with 11000.54 (43.43%), followed by fertilizer application and sowing (with 24.84% and 16.67%) were highly contributed to the total energy use for small marginal farmers. For medium marginal farmers; Irrigation with 10835.27 (33.81%), followed by fertilizer application and sowing (with 28.24% and 20.68%) were highly contributed to the total energy use and for large marginal farmers; fertilizer application with 17597.66 (31.68%) followed by sowing and irrigation (with 25.30% and 19.12%) were highly contributed to the total energy use however the total physical energy input consumption was 19203.81, 32043.23, 55549.24 MJ for small, medium and large marginal wheat farmers; in which water with 5817.59 (30.29%) followed by electricity and nitrogen (27.85% and 16.30%) were highly contributed to the total energy use for small marginal farmers. For medium marginal farmers; nitrogen with 8017.21 (25.02%), followed by electricity and seed (18.59% and 17.53%) were highly contributed to the total energy use and for large marginal farmers; nitrogen with 15333.88 (27.60%) followed by seed and diesel fuel (with 21.57% and 13.81%) were highly contributed to the total energy use. Energy ratio, energy productivity and net energy were higher in large marginal farmers with 3.97, 0.27 kg/MJ and 165095 MJ respectively while specific energy was found higher for small marginal wheat farmers with 0.52 MJ/kg. Nitrogen, pesticide and electricity positively significant while diesel fuel is negatively significant with 54% R2 for small marginal farmers; potassium, human labour, machinery and water positively significant while fym is negatively significant with 54% R2 while for large marginal farmers, human labour and electricity negatively significant with 45% R2.

Keywords: wheat, energy coefficient, energy ratio, specific energy, multi linear regression

1. Introduction

Production agriculture is an energy conversion industry, Natural ecosystem run on self–regulating manner to convert solar and chemical energies to storable chemical energy in form of food products or carbohydrate. All biomass, including fuel wood, crop and livestock residues and processing wastes is the result of present or past photosynthesis. Apart from solar energy, production agriculture uses additional energy inputs through soil, water, tractive power, chemicals for growth of plants. The amount of energy invested through these inputs and the quantity actually used by the plants govern the crop growth and yield during their life cycle. Traditional agriculture was mostly dependent on non-commercial energy sources. In modern agriculture, commercial energy sources (fuel, machinery and chemical) contribute bulk of the energy supplies to the production system.

Agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energies, such as seed, manure and animate energy, and commercial energies directly and indirectly in the form of diesel, electricity, fertilizer, plant protection, chemicals, irrigation water and machinery. Efficient use of energies helps to achieve increased production and productivity and contributes to the economy, profitability and competitiveness of agriculture sustainability in rural living (Singh *et al*., 2002) [5]. The extents of agricultural inputs have been increasing over years leading to higher productivity.

Energy auditing is one of the most common approaches to assess energy efficiency and environmental impact of the production system.

It enables the researchers to calculate the output–input ratio, relevant indicators for energy and energy use patterns in an agricultural activity (Hatirli *et al*., 2006) [3]. Energy audit of various villages under different agro-climatic zones has shown that among different farm operations, irrigation alone consumes 51% of total energy used in various farm operations (Singh and Singh, 2001) [4]. Harvesting and threshing and seedbed preparation consumed 19% and 13% respectively of total energy in operations. These three operations together consume 83% of operational energy. Therefore, they are the most important farm operations from energy use point of view. Among different energy sources, maximum energy input is derived from fertilizers and chemicals (28%) followed by diesel (26%), electricity (16%) and seeds (9%) (Singh and Singh, 2001) [4].

1.1 Wheat

Wheat crop has wide adaptability. It can be grown not only in the tropical and sub-tropical zones, but also in the temperate zone and the cold tracts of the far north, beyond even the 60 degree north altitude. Wheat can tolerate severe cold and snow and resume growth with the setting in of warm weather in spring.

It can be cultivated from sea level to as high as 3300 meters

The best wheat are produced in areas favoured with cool, moist weather during the major portion of the growing period followed by dry, warm weather to enable the grain to ripen properly. The optimum temperature range for ideal germination of wheat seed is 20-25 ^{0}C though the seeds can germinate in the range 3.5-35 ^{0}C Rains just after sowing hamper germination and encourage seedling blight.

Areas with a warm and damp climate are not suited for wheat growing.

Wheat is an important source of carbohydrates. Globally, it is the leading source of vegetal protein in human food, having a protein content of about 13%, which is relatively high compared to other major cereals but relatively low in protein quality for supplying essential amino acids. When eaten as the whole grain, wheat is a source of multiple nutrients and dietary fibre.

In a small part of the general population, gluten – the major part of wheat protein can trigger coeliac disease, non coeliac gluten sensitivity, gluten ataxia, and dermatitis herpetiformis (Anon., 2019) [1].

1.2 Agriculture and Energy

In our country, energy use in agriculture has been increasing since a green Revolution in the late seventies with increasing use of high yielding seed varieties, synthetic fertilizers, agro-chemicals, as well as diesel and electricity in farm-operations. The pattern and rate of growth of demand for energy sources is influenced by a number of factors as increasing population, growing urbanization, rising house hold income, changing life styles and structural changes taking place in the economy. Increase in land productivity and efficient diversification of agriculture for better economic return to the producers will call for significantly higher level of energy input to agriculture.

Agriculture in India has gone into more or less total transformation from organic to inorganic agriculture. Increasing use of commercial energy has made agriculture move with fast stride. Energy as an input is attaining higher demands with the growth of agricultural production that is priority goal in agriculture and energy is the interactive relationship between energy and other agricultural production inputs. Besides direct uses of energy as fuels, fossil-fuel energy inputs to agricultural production systems are also represented as indirect energy requirements for land, labour, water, machinery etc.

With increasing demand on commercial energy resources in production and processing of agro- produces, energy management would play a key role in developing regional/national coherent and implementable strategies for energy conservation, adopting energy efficient technologies as well as determining an appropriate energy resources-mix of conventional and renewable energy resources for minimizing energy cost.

A reliable supply of energy, in the right form, at the right time and at affordable prices, is an essential pre-requisite for high agricultural productivity. During the decade from the mid-70’s to mid 80’s hundreds of research projects were conducted around the world with the general goals of (i) improving the efficiency of energy utilization, or (ii) developing alternatives to petroleum or natural gas for use in agriculture and the food industry.

1.3 Why do we need energy?

Land is the main source of food for Indian population but the fertility of cultivable land as well as its total availability is mostly given by the nature. The total land area of India is 328 million ha out of 328 million ha land. An estimated 142 million ha is cultivated area, of which about 55 million ha is irrigated and remaining 87 million ha is rain fed. To boost crop production, human efforts are therefore, required to improve both the quality of land and the level of land use. The farmers are accomplished by the application of inputs, which raise the productivity levels of crops. Improvements of land use, on the other hand, have two dimensions: extension of the net area sown, and multiple cropping of land. Since the prospects of further extending the net area sown is rather limited in India, extension of multiple cropped area is an important means of improving land use and thereby production. In Indian conditions it is possible to grow as many as three crops in a year, but in reality the average cropping intensity is little over 1.35 and also varies from state to state. In a land scare but labour-abundant country like India, a high cropping intensity is desirable not only for full utilization of land resources to achieve higher production level, but also for reducing seasonal unemployment in the rural economy and for achieving greater stability in food supply.

Energy is considered to be a key player in a generation of wealth and also a significant component in economic development. Energy consumption per unit area in agriculture is directly related with the development of technological level and production. The inputs such as fuel, electricity, machinery, seeds, fertilizers and chemicals take significant share of the energy supplies to the production system in modern.

agriculture. The use of intensive inputs in agricultural and access to plentiful fossil energy has provided an increase for standards of living and food production. However, some problems in agricultural production have been faced due to mainly high level dependency on of fossil energy. Furthermore, considering that fossil energy is a limited resource, it has to be conserved for future generations by using efficiency in a sustainable manner. This makes energy resources extremely significant for every country in the world.

Efficient use of the energy resources is vital in terms of increasing production, productivity, competitiveness of agriculture as well as sustainability to rural living. Energy auditing is one of the most common approaches to examine energy efficiency and environmental impact of the production system. Moreover, the energy audit provides sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs. Estimating these forms is very useful in determining elasticity of inputs on yield and production. Energy use pattern and contribution of energy inputs vary depending on farming systems, crop season and farming conditions. Considerable work has been conducted on the use of energy in agriculture with respect to efficient and economic use of energy for sustainable production. Energy input-output analysis is usually used to evaluate the efficiency and environmental impacts of production system. Optimization of energy use in agriculture is reflected in two ways, i.e. an increase in productivity at the existing level of energy inputs or conserving the energy without affecting the productivity.

Solution of the energy crisis is strongly dependent on the technology of how energy is used. To make a physical change in the world it is necessary to use four resources; energy, matter, space and time. How well a task has been performed can be measured in terms of the amount of fuel consumed, the mass of material used, the space occupied, the hours of labour to accomplish it, and the ingenuity with which these resources are utilized. The era of cheap energy is now ending and the populace will necessarily become energy conservation conscious; first because of the rising cost for energy, but later because of the dire consequences in placing additional stresses on our biosphere, already showing serious signs of the strain.

2. Material and methods

Saurashtra region of Gujarat is located within 21.85˚ north latitude and 70.81˚ east longitude. It is surrounded by Arabian Sea on the south and south-west; Gulf of Kutch on north-west, Gulf of Khambhat and North Gujarat on the east. The geographical proximity of the region with the middle-east via sea routes gives the region its locational advantage. The eleven districts of the region, spreads across 64,383 sq. km of area occupying 33% of the total landmass of the state. The region has 25.5% (15.4 million) of state's population with 43% urban population. . The Amreli, Bhavnagar, Botad, Devbhoomi dwarka, Jamnagar, Rajkot, Surendra nagar and Morbi is lied in North saurashtra agro climatic zone while Junagadh, Porbandar and Veraval is lied in South saurashtra agro climatic zone.

The primary data was collected with the help of well-prepared questionnaires by seeking face-to- face conversation of the sample farmer. The data of energy input resources for wheat cultivation was collected from the three different categories of the farmers' i.e. small (less than ha), medium (1 ≥ 3 ha) and large (≤ 3 ha) farmers based on the size of land holding.

The proportionate number of the farmers of each category was selected based on the percentage share of that category into the total population of the farming households. The data of different inputs used for field operations (land preparation, cultural practices, management, chemical fertilizers, pesticides and harvesting) was collected from all categories of the farmers. The data of energy inputs from different physical sources (human, animal and machinery etc.) As well as in the farm of material (seed, fertilizer and chemicals etc.) was collected through personal interviews of the farmers. Data was collected by using a face to face questionnaire performed with 605 farmers (55 farmers of each district) from eleven (11) districts of Saurashtra region in Rabi 2019-2020 in which 287 small farmers, 288 medium farmers and 30 large farmers were selected.

The questionnaire was structured as per using our research objectives, and the views of experts in the international and national literature.

The sample size was calculated using the Yamane (1967) method.

$$\mathbf{n} = \frac{\mathbf{N}}{1+\mathbf{N}\,(\mathbf{e})^2} \qquad (1)$$

Where n is the sample size, N is the population size (>1, 00,000), and e is the level of precision (0.05%).

The multi linear regression method was used for the analysis. It is the regression model. A regression model is a statistical model that estimate the relationship between one dependent variable and one or more independent variables using a line (or a plane in the case of two or more independent variables)

$$y_i = \beta 0 + \beta 1 x_{i1} + \beta 2 x_{i2} + \ldots\ldots\ldots + \beta n x_{in} + \varepsilon \qquad (3.2)$$

Where

yi is the dependent or predicted variable

β0 is the y-intercept, i.e., the value of y when both xi and x2 are 0.

β1 and β2 are the regression coefficients that represent the change in y relative to a one-unit change in xi1 and xi2, respectively.

βn is the slope coefficient for each independent variable ϵ is the model's random error (residual) term.

2.1 Energy Use Pattern of Wheat Cultivation

The calculation of the energy inputs was based on a task schedule (time needed for each operation), the number of workers and the machinery and input used (seed, fertilizer, chemicals). Energy equivalents of the inputs was used in the wheat productions are illustrated in Table 1 In the literature, there is enormous variation in energy equivalents used to express the input of energy associated with the manufacture of production means in terms of primary energy input. Energy is primarily used in agricultural operations for tillage, hoeing, pruning, transportation, irrigation, fertilizer application, spraying, harvesting, etc.

The input energy was examined as direct (human labour, animal, petrol, diesel, electricity and canal) and indirect (seeds, fertilizers, farm yard manure, chemicals, machinery), renewable (human labour, animal, seeds, farmyard manure, canal) and non-renewable (petrol, diesel, electricity, chemicals, fertilizers,
machinery), commercial (petrol, diesel, electricity, chemicals, fertilizers, seeds, machinery) and non- commercial (human labour, animal, farm yard manure, canal) forms.

First, the most common production systems for the crop was determined; then all inputs and outputs to and from the system was identified and quantified; later they was transformed into energy units. The energy equivalents of inputs and outputs are shown in Table 1.

2.2 Energy audit in production of Wheat Cultivation

Energy auditing is one of the most common approaches to assess energy system. On the other hand, the energy audit provides sufficient data to established functional forms to investigate the relationship between energy inputs and outputs. Energy analysis takes into account all forms of energy inputs to the production system and energy outputs from the system and establishes energy relationship for understanding the energy conversion process. Total energy input and output of the present study system components was calculated and converted to their energy equivalents of inputs and outputs wheat production. wheat was sown by broadcast method or by tractor with the help of Auto seed cum fertilizer drill equipment in the region. Therefore, the energy equivalences for small marginal, medium marginal and large marginal farmers was calculated by combining the energy inputs, seed, farmyard manure, chemicals, human, and fertilizer, in the crop production. Energy output–input ratio, specific energy, energy productivity and energy intensiveness was calculated using the data recorded as per eq. 2 to 4.

The working hours of the employees was determined in each operation and pooled to get total human energy. The total human energy use on each farm was calculated by suitable conversion factors, 1 man-hour = 1.96 MJ ha-1 (Table 1) The mechanical energy use on each farm operations was calculated by suitable conversion factors (Table 1).

2.3 Energy indicators for wheat cultivation

The following different energy efficiency parameters were determined to evaluate relationship between energy consumption and total output and production for the particular area. Energy ratio, specific energy, energy productivity and net energy yield was calculated using the following formula as suggested by (Canakci et al., 2005; Hatirli et al., 2006; Yousefi and Darijani, 2011) [2, 3, 7]. Input-output analysis was done to examine the quantity of energy produced by the system against the energy expenditure.

2.3.1 Crop yield: Crop yield is the total amount of yield produced per unit of area (kg).

$$\text{Energy ratio} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}} \quad (2)$$

Energy output-input ratio shows the efficiency of energy input and also marginal increase of output due to per unit increase in energy input. This ratio is generally higher in lower energy input and lower in higher energy input, which indicates the low of diminishing returning applied in energy input. Energy efficiency is a useful physical measurement. However, it is by no means an indication for agricultural.

economic efficiency. Thus, we should not be surprised to find highly efficient agricultural sectors operating with very low energy efficiency.

2.3.2 Specific energy

It has been widely used in energy analysis to express the quantity of Energy invested to produce unit quantity of the product. Specific energy can be defined as energy consumed in crop production per unit of crop produced (MJ/ha).

$$\text{Specific energy (MJ/kg)} = \frac{\text{Total energy input (MJ/ha)}}{\text{Crop yield (kg/ha)}} \quad (3)$$

Specific energy (MJ/kg) has been widely used in energy analysis to express the quantity of energy invested to produce unit quantity of the product.

2.3.3 Energy productivity

Energy productivity which measures the quantity of the product Produced per unit of input energy.

It is the inverse of specific energy. This serves as an evaluator of how efficiently energy is utilized in the production system yielding a particular product. Energy productivity is the ratio of crop yield and total energy consumed during crop production (kg/MJ).

$$\text{Energy Productivity (kg/MJ)} = \frac{\text{Crop yield (kg/ha)}}{\text{Energy input (MJ/ha)}} \quad (4)$$

Energy productivity, which measures the quantity of product produced per unit of input energy (kg/MJ), is the inverse of specific energy. This serves as an evaluator of how efficiently energy will be utilized in the production system yielding a particular product.

3. Result and Discussion.

This chapter deals with the findings and discussion of the study. The facts and finding derived after analyzing the information have been presented in this chapter under following heads.

- Energy use pattern of wheat production in the region.
- Energy consumption (MJ) in different agronomic practices in the wheat production of the region.
- Energy indices of wheat production in the region.
- Energy forms of wheat production in the region.
- Energy input and crop yield relations
- An analysis of energy input and output in the field of wheat production in the region.

3.1 Energy use pattern of wheat production in the saurashtra region

Table 2 offers a comprehensive summary of energy consumption (MJ) in three farm sizes of wheat production in the surveyed region. It can be seen from the Table 2 that inputs used in wheat production and their energy equivalents, percentages in the total energy input and output. Total energy consumption for nitrogen, phosphorous, potassium, sulphur, pesticide, human labour, machinery, FYM, seed, diesel, water and electricity energy consumption is 3130.18, 8017.21, 15333.88 MJ, 376.74, 992.81, 2148.10 MJ, 5.46, 18.05, 70.53 MJ, 0, 1.13, 0 MJ, 4.56, 1.25, 2.15 MJ, 142.31, 349.43, 476.30 MJ, 588.59, 1461.27, 3070.34 MJ, 833.62, 1654.17, 4170.00 MJ, 2024.35, 5616.22, 11984.17 MJ, 931.62, 3096.44, 7674.09 MJ, 5817.59, 4878.47, 3593.61 MJ and 5348.80, 5956.80, 7026.08 MJ respectively. It can be seen from Table 2 and Figure 1 that the highest share of Total energy input in small marginal wheat farms was calculated for water for irrigation (30.29%), electricity (27.85%) and nitrogen (16.30%), while this amount in medium marginal wheat farms was recorded as the nitrogen (25.02%), electricity (18.59%) and seed (17.53%) however for the large marginal farms it was found nitrogen (27.60%), seed (21.57%) and diesel fuel (13.81%). It can be seen from Table 2, the results showed that the total energy input and energy output in wheat production is 19203.81, 32043.23, 55549.24 MJ and 36765.35, 103197.43, 220644.67 MJ for small, medium and large marginal wheat farms respectively.

3.2 Energy consumption (MJ) in different agronomic practices of wheat production in the region

The use of power sources for the wheat production in the region are given in Table 3. The total energy input used in various farm operations for cultivating the wheat was calculated to be 25327.58,

32043.23 and 55549.24 MJ for small, medium and large marginal farmers respectively. Out of all the operations, irrigation consumed the maximum energy followed by fertilization and sowing with the ratio of 43.43, 24.84, and 16.67% for small marginal farmers respectively while for the medium marginal farmers the irrigation consumed higher energy followed by fertilization and sowing with the ratio of 33.81, 28.24 and 20.68% respectively. However, the fertilization (31.68%) consumed more energy followed by sowing (25.30%) and irrigation (19.12%) for large marginal wheat farmers. It is shown in Fig. 2 that pesticide application was the least demanding energy input for small, medium and large marginal wheat production with 5.13, 3.73, 11.50 MJ (only 0.02, 0.01, 0.02% of the total energy input), followed by weeding 110.38, 164.97, 74.20 MJ (0.44, 0.51 0.13%) respectively.

3.3 Energy indices of wheat production in the region

It can be seen from Table 4 that energy use efficiency, energy productivity, specific energy, and net energy were calculated for small marginal groundnut farmers, medium marginal groundnut farmers and large marginal groundnut farmers. In energy balances the energy ratio is often used as an index to examine the energy efficiency in crop production Energy ratio is one of the best energy indices that shows the efficient use of energy in groundnut production. The average value of energy use efficiency was calculated as 3.04, showing the 3.04-unit output energy is obtained per unit energy consumption. Energy use efficiency and Energy productivity of large marginal wheat farmers was higher than medium and small marginal wheat farmers. Specific energy was found to be higher in small marginal wheat farmers than large and medium marginal wheat farmers. Net energy (total output energy minus total input energy) in small marginal wheat production was 165095 MJha-1 while this amount for small, medium and large marginal farmers are 17561.5, 71154.2and 165095 MJha-1 respectively. This means that amount of output energy is higher than input energy.

3.4 Energy forms wheat production in the region

Different energy input forms as direct and indirect are also shown in Table 5 and Figure 5, where the share of direct and indirect forms was 36.261 and 63.739% for small marginal wheat farmers while this amount was 55.43 and 44.57% for medium marginal wheat farmers however for large marginal wheat farmers the direct and indirect forms were 66.21 and 33.79% respectively. It was understood that the proportion of indirect energy use in large marginal wheat farmers was higher than small and medium marginal wheat production while for direct energy use in small marginal farmers was higher than large and medium marginal farmers. It can be seen from Fig. 5 shows that water for irrigation had the most energy consumption followed by electricity for small marginal wheat farmers while nitrogen is the more energy consumptive input followed by electricity for medium marginal wheat farmers however, for large marginal wheat farmers nitrogen is the most energy consumption input followed by seed.

3.5 Energy input and crop yield relations

The plots of total energy input versus crop yield are presented in Table 9 and Fig. 3 to for wheat production. It can be shown from table that crop yield in wheat is increased as a function of the energy inputs. The coefficients of determination (R2) between yield and total energy input for Saurashtra 0.97. It implies that the variation in total energy input for wheat in Saurashtra had a major influence (97%).

3.6 An analysis of energy input and output in the field of wheat

The small marginal wheat farmers yield (endogenous variable) was assumed to be a function of nitrogen, phosphorus, potassium, pesticide, human labour, machinery, FYM, seed, diesel fuel, water and electricity (exogenous variables) which revealed that, the impacts of nitrogen, phosphorus, potassium, pesticide, machinery, FYM, seed, water, electricity were 3.02, 11.58, 38.05, 215.20, 6.60, 0.60, 1.47, 0.37,

1.77 respectively. Pesticide had the highest impact among the other inputs in wheat production indicating that by increasing energy obtained from pesticide input, the amount of yield improves in present condition. Pesticide had the least amount of energy consumption; namely, the increase in energy usage terminates in yield addition.

Regression equation for yield of small marginal wheat farmers with its independent variable and estimated coefficients are presented in Table 7. The regression equation for small marginal wheat farmers R2 was found to be 54% that means 54% variation in the data is explained by independent variables. From Nitrogen, phosphorus, potassium, pesticide, human labour, machinery, FYM, seed, diesel fuel, water and electricity (eleven) independent variables nine independent variables were found to be positive and two independent variables were found to be negative. From eleven independent variables four variables are significant. Nitrogen, Pesticide, diesel fuel and electricity were found to be significant at 1% level of significance. nitrogen, pesticide and electricity were found to be positively significant at 1% level of significance however diesel fuel was found to be negative significant at 1% level of significance rest of the independent variable were found to be non significant that means these variables were not having any influence in results.

It was assumed that the medium marginal wheat farmers yield (endogenous variable) to be a function of nitrogen, phosphorus, potassium, pesticide, human labour, machinery, FYM, seed, diesel fuel,

water and electricity (exogenous variables) which revealed that, the impacts of nitrogen, phosphorous, potassium, pesticide, human labour, machinery, diesel fuel, water and electricity were 0.17, 11.32, 95.11, 26.09, 51.66, 3.06, 1.36, 1.90, respectively. Potassium had the highest impact among the other inputs, followed by machinery in wheat production indicating that increase in the energy obtained from potassium input, the amount of yield improves in present condition. potassium had the least amount of energy consumption; namely, the increase in energy usage terminates by yield addition.

Regression equation for yield of medium marginal wheat farmers with its independent variable and estimated coefficients are presented in Table 8. The regression equation for medium marginal wheat farmers R2 was found to be 54% that means 54% variation in the data is explained by independent variables. From Nitrogen, phosphorus, potassium, pesticide, human labour, machinery, FYM, seed, diesel fuel, water and electricity (eleven) independent variables, eight independent variables were found to be positive and three independent variables were found to be negative. From eleven independent variables, five variables are significant. Potassium, Machinery, FYM and water was found to be significant at 1% level of significant and Human labour was found to be positively significant at 5% level of significant however, Potassium, human labour, machinery and water were found to be positively significant, while FYM was found to be negatively significant, rest of the independent variable were found to be non significant that means these variables were not having any influence in results.

It was assumed that the large marginal wheat farmers yield (endogenous variable) to be a function of nitrogen, phosphorus, potassium, pesticide, human labour, machinery, FYM, seed, diesel fuel, water and electricity (exogenous variables) which revealed that, the impacts of nitrogen, potassium, machinery, FYM, seed, diesel fuel, water were 1.96, 3.98, 96.67, 14.12, 0.08, 5.61, 6.21 1.44 respectively. Potassium had the highest impact among the other inputs followed by machinery in wheat production indicating that by increase in the energy obtained from potassium input, the amount of yield improves in present condition. potassium had the least amount of energy consumption; namely, the increase in energy usage terminates in yield addition.

Regression equation for yield of large marginal wheat farmers with its independent variable and estimated coefficients are presented in Table 9. The regression equation for medium marginal cotton farmers R2 was found to be 45% that means 45% variation in the data is explained by independent variables. From Nitrogen, phosphorus, potassium, pesticide, human labour, machinery, FYM, seed, diesel fuel, water and electricity (eleven) independent variables, eight independent variables were found to be positive and three independent variables were found to be negative. From eleven independent variables, two variables are significant. Human labour and electricity was found to be positively significant at 5% level of significance while rest of the independent variable were found to be non significant that means these variables were not having any influence in results.

Table 1: Energy coefficient for different farm equipments

Equipment	Energy equivalnet (MJ)	
	Tractor	Animal
M B plough	2.508	0.627
Blade harrow	8.336	3.135
Cultivator	3.135	0.627
Disc harrow	7.336	3.135
Rotavator	10.283	-
Levellor	4.703	-
Disc plough	3.762	-
Furrow opener	2.508	0.627
Thresher	7.524	-
Diesel engine	0.581	0.581
Plough	-	0.314
Planker	9.405	3.135
Seed drill	8.653	1.568
Puddler	2.508	1.254
Bund former	-	1.442
Cart	-	5.204
Trailer	17.431	-
Equipment	**Energy equivalnet (MJ)**	
Tractor (45)	16.416	
Tractor (other)	10.944	
Electric motor	0.216	
Diesel	56.31	
Trailer	17.431	
Bullocks	10.1	
Men	1.96	
Thresher	7.524	
Petrol	48.23	
Electricity	11.93	
Water	1.03	
Chemicals	120	
Sickle	0.031	
nitrogen	60	
phosphorus	11.1	
potassium	6.7	
sulphur	1.2	
Fertilizer	**Energy equivalnet (MJ)**	
Amonnium sulphate	25.272	
Single super phosphate	2.58	

Double super phosphate	4.356	
12 32 16	23.648	
20 20 13	30.182	
fada suphur	4.46	
arandi no khod	1.08	
FYM	0.3	
Crop	**Energy equivalnet (MJ)**	
Wheat	14.7	

Table 2: Physical inputs used in the production of wheat yield

Particulars			**Quantity**		**Total energy equiva**		**lent, MJ**	**p**	**ercentag**	**e**
A. Inputs (MJ)	**unit**	**<1 ha**	**1-3≤ ha**	**>3 ha**	**<1 ha**	**1-3≤ ha**	**>3 ha**	**<1 ha**	**1-3≤ ha**	**>3 ha**
Nitrogen	kg	52.17	133.62	255.56	3130.18	8017.21	15333.88	16.30	25.02	27.60
Phosphate (P2O5)	kg	33.94	89.44	193.52	376.74	992.81	2148.10	1.96	3.10	3.87
Potassium (K2O)	kg	0.81	2.69	10.53	5.46	18.05	70.53	0.03	0.06	0.13
Sulfer	kg	0.00	0.94	0.00	0.00	1.13	0.00	0.00	0.00	0.00
Pesticide	l	0.04	0.01	0.02	4.56	1.25	2.15	0.02	0.00	0.00
Human labour	h	72.61	178.28	243.01	142.31	349.43	476.30	0.74	1.09	0.86
Machinery	h	9.08	22.55	47.38	588.59	1461.27	3070.34	3.06	4.56	5.53
Farmyard manure	kg	2778.75	5513.89	13900.00	833.62	1654.17	4170.00	4.34	5.16	7.51
Seed	kg	137.71	382.06	815.25	2024.35	5616.22	11984.17	10.54	17.53	21.57
Diesel fuel	l	16.54	54.99	136.28	931.62	3096.44	7674.09	4.85	9.66	13.81
Water for irrigation	m3	5648.15	4736.38	3488.94	5817.59	4878.47	3593.61	30.29	15.22	6.47
Electricity	kWh	448.35	499.31	588.94	5348.80	5956.80	7026.08	27.85	18.59	12.65
B. Total energy input		9198.15	11614.17	19679.44	19203.81	32043.23	55549.24	100	100	100
C. Wheat yield		2501.04	7020.23	15009.84	36765.35	103197.43	220644.67			

Table 3: Operation and source wise energy input for wheat crop production

Sources (MJ)	**Total energy equivalent, MJ**			**Percentage**		
	<1 ha	**1-3≤ ha**	**>3 ha**	**<1 ha**	**1-3≤ ha**	**>3 ha**
Site preparation	684.55	929.41	1893.71	2.70	2.90	3.41
Irrigation	11000.54	10835.27	10619.69	43.43	33.81	19.12
FYM application	1441.86	1916.33	4830.89	5.69	5.98	8.70
Fertilization	6290.14	9049.34	17597.66	24.84	28.24	31.68
Sowing	4221.00	6626.96	14054.39	16.67	20.68	25.30
Weeding	110.38	164.97	74.20	0.44	0.51	0.13
Pesticide application	5.13	3.73	11.50	0.02	0.01	0.02
Harvesting & threshing	1573.98	2517.20	6467.22	6.21	7.86	11.64
Energy sources total	25327.58	32043.23	55549.24	100.00	100.00	100.00
crop yield	36765.35	103197.43	220644.67			

Table 4: The indicators of energy use in different wheat production systems

Energy indices	**Units**		**Wheat**		**Average**
		<1 ha	**1-3≤ ha**	**>3 ha**	
Energy ratio	-	1.91	3.22	3.97	3.04
Energy productivity	Kg/MJ	0.13023	0.2190	0.27020	0.21
Specific energy	MJ/kg	0.52233	0.3105	0.25176	0.36
Net energy	MJ	17561.5	71154.2	165095	84603.72

Table 5: Total energy input in the form of direct, indirect energy for wheat production

Indirect energy (%)			
Energy form (MJ)	**<1 ha**	**1-3≤ ha**	**>3 ha**
Nitrogen	16.2998	25.02	27.6041
Phosphate (P2O5)	1.96177	3.09834	3.86702
Potassium (K2O)	0.02842	0.05633	0.12697
Sulphur	0	0.00352	0
Pesticide	0.02372	0.00391	0.00387
Farmyard manure	4.34093	5.1623	7.50685
Machinery	3.06497	4.5603	5.52724
Seed	10.5414	17.527	21.574
Total	36.261	55.4317	66.21
Direct energy (%)			
Energy form (MJ)	**<1 ha**	**1-3≤ ha**	**>3 ha**
Human labour	0.74105	1.09049	0.85744

Electricity	27.8528	18.5899	12.6484
Diesel fuel	4.85122	9.66331	13.8149
Water for irrigation	30.2939	15.2247	6.46923
Total	63.739	44.5683	33.79

Table 6: Crop yield versus total energy input of wheat for Saurashtra region

Wheat crop	**<1 ha**	**1-3≤ ha**	**>3 ha**
Total energy input (MJ)	19203.8	32043.23	55549.24
wheat yield (kg)	2501	7020	15010

Table 7: Effect of different input variables on small marginal wheat farmers

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Intercept	4109	3870.26	1.06168	0.29128
Nitrogen**	3.02548	0.72481	4.17418	7E-05
Phosphorus	11.5842	9.76735	1.18601	0.23881
potassium	38.0491	37.3189	1.01957	0.31073
Pesticide**	215.198	71.1646	3.02395	0.00327
human labour	-4.411	6.74393	-0.6541	0.51477
Machinery	6.59727	4.93467	1.33692	0.18469
FYM	0.60236	0.40715	1.47944	0.14259
Seed	1.47563	1.37359	1.07429	0.28563
diesel fuel**	-5.4807	1.91394	-2.8635	0.00524
water	0.37124	0.26867	1.38178	0.17054
Electricity**	1.77014	0.64121	2.76064	0.00702

R2 = 0.54 Adjusted R2 = 0.49

* & ** indicate significance at 5% and 1% level of significance, respectively.

Table 8: Effect of different input variables on medium marginal wheat farmers

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Intercept	16154.2	15822.7	1.02095	0.31106
Nitrogen	0.17374	0.95767	0.18142	0.8566
Phosphorus	11.3166	9.4651	1.19561	0.23619
Potassium**	95.1142	37.6205	2.52825	0.0139
Pesticide	-892.51	658.098	-1.3562	0.17973
human labour*	26.0897	12.3776	2.10781	0.03891
Machinery**	51.6605	8.49733	6.07961	7.1E-08
FYM**	-3.376	1.15275	-2.9287	0.00469
Seed	-2.0815	1.75267	-1.1876	0.2393
diesel fuel	3.06089	8.64339	0.35413	0.72439
water **	1.36385	0.48053	2.8382	0.00605
Electricity	1.90064	1.5019	1.26549	0.21021

R2 = 0.54 Adjusted R2 = 0.46

* & ** indicate significance at 5% and 1% level of significance, respectively.

Table 9: Effect of different input variables on large marginal wheat farmers

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Intercept	154382	82277.7	1.87635	0.07282
Nitrogen	1.95797	1.9148	1.02255	0.31672
Phosphorus	3.97651	18.605	0.21373	0.83256
Potassium	96.6618	80.3398	1.20316	0.24065
Pesticide	-2488.9	5537.2	-0.4495	0.65711
human labour*	-231.1	114.368	-2.0206	0.05461
Machinery	14.1242	16.7142	0.84504	0.40643
FYM	0.08419	1.35791	0.062	0.95108
Seed	5.60637	4.09416	1.36936	0.18357
diesel fuel	6.21632	3.4862	1.78312	0.08722
water	1.43934	5.66212	0.2542	0.8015
Electricity*	-11.638	4.85179	-2.3987	0.02458

R2 = 0.45 Adjusted R2 = 0.20

* & ** indicate significance at 5% and 1% level of significance, respectively.

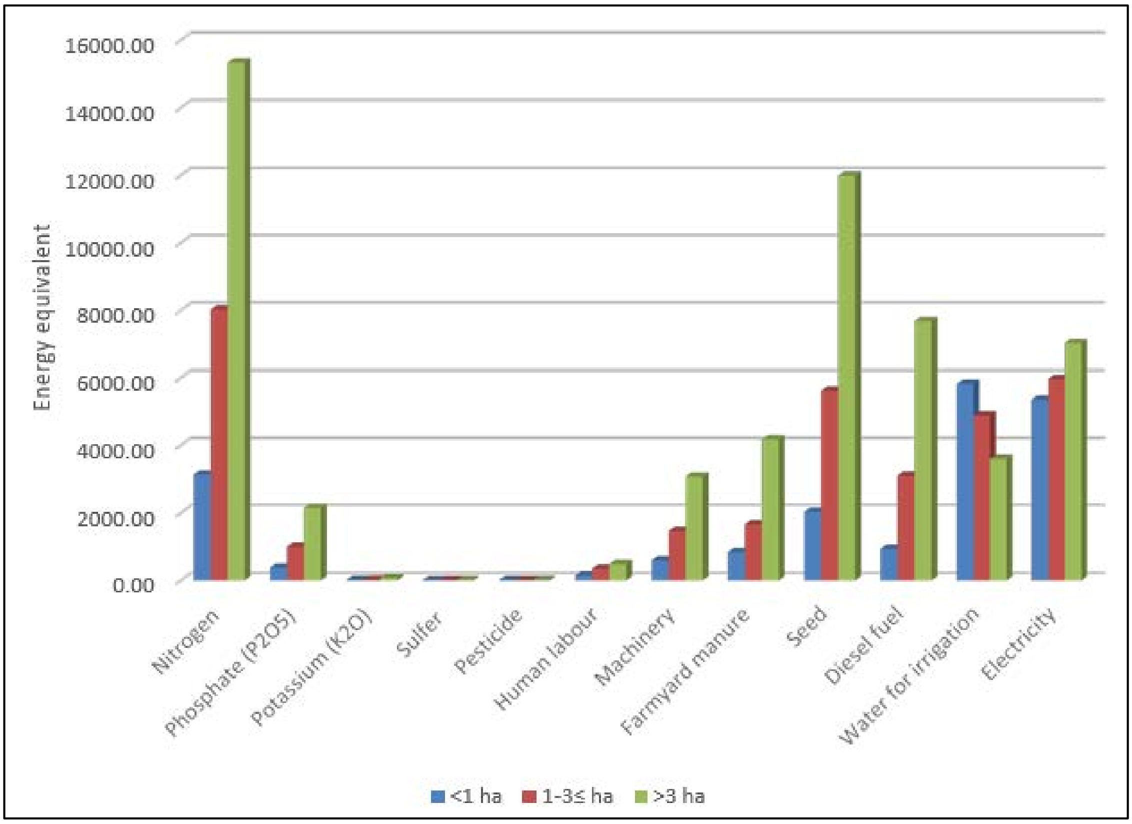

Fig 1: Energy utilization pattern in Inputs for wheat production

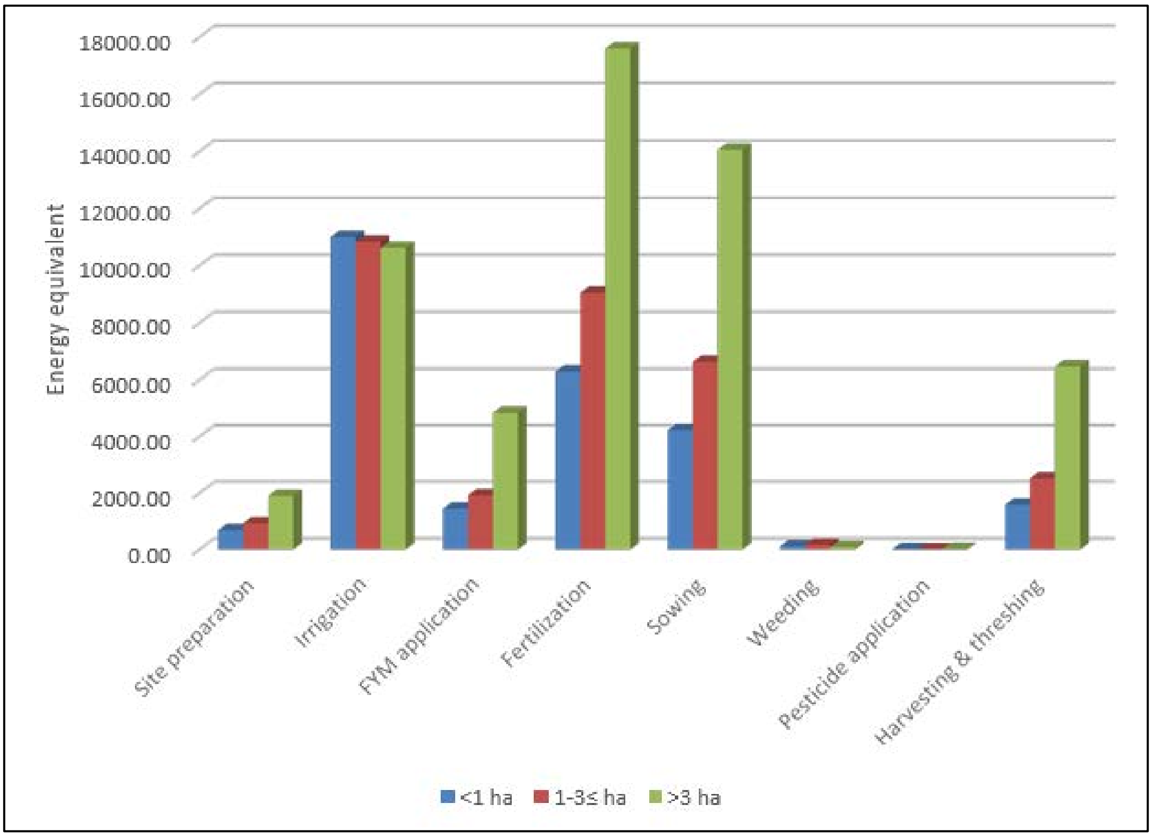

Fig 2: The distribution of energy source ratios in the wheat production

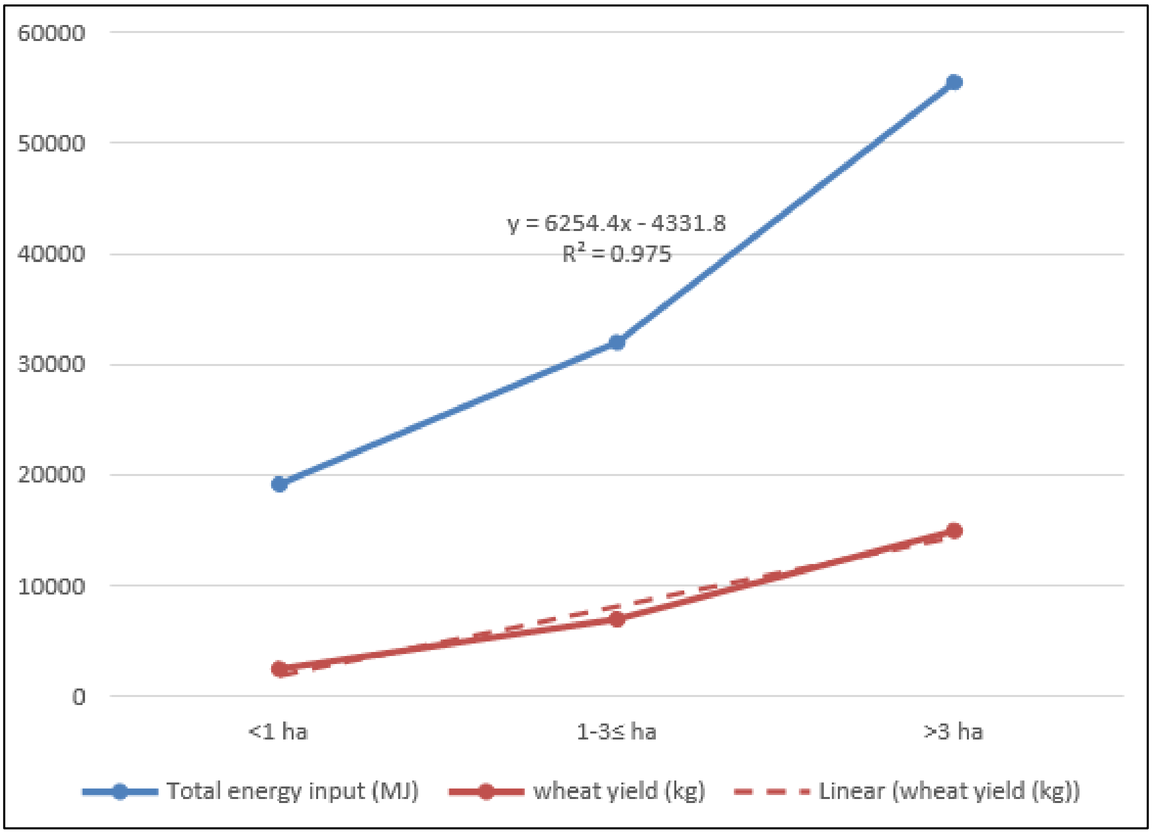

Fig 3: Crop yield versus total energy input for wheat crop

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