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Land holding effect on energy inputs for soybean production in Malwa plateau of Madhya Pradesh

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***Abstract**: The aim of this study were to determine the input–output energy used in soybean production to investigate the efficiency of energy consumption of soybean production under different farmer's category. Data used in this study were collected randomly from 128 farmers of Malwa plateau by using a face to face questionnaire method. The farmers were classified into four categories of marginal (less than 1 ha), small (1 to 2 ha), medium (2 to 4 ha) and large farmers (more than 4 ha). The results indicated that total energy consumed by large farmers was found to be 10385 MJ/ha followed by medium farmers (9317 MJ/ha), small (8094 MJ/ha) and marginal (7749 MJ/ha). The highest yield value (1564 kg/ha) was obtained from large farmers followed by medium (1443 kg/ha), small (1307 kg/ha) and marginal farmers (1278 kg/ha). The results also revealed that energy use efficiency (4.28) was found for marginal farmers and decreased as the farm size increased. Marginal farmers were more successful in energy use efficiency, indicating a better management of energy and input consumptions. It was concluded that energy management at farm level could be improved to give more efficient and use of energy.*
***Keywords**: energy; input-output; land holdings; soybean*

I. Introduction

Soybean (*Glycine max* L.) is an important oil seed crop. The total area under soybean cultivation in India is10.69 million hectare and total production is 12.67 million tonnes with average productivity of 1185 kg/ha. The area, production and productivity of soybean in the states of Madhya Pradesh are 5.81 million hectare, 6.68 million tonnes and 1050 kg/ha, respectively [1]. Madhya Pradesh is as major soybean producing state contributing 54.35 per cent in area 52.72 per cent in production to soybean cultivation of all over India.

Energy consumption in agriculture for developing countries has been increasing rapidly due to recent economic growth and development [2]. However, increased input use in agricultural production may not bring maximum profits due to increasing production costs [3]. Energy, economics, and the environment are mutually dependent [4]. The productivity and profitability of agriculture depend upon energy use. The amount of energy used depends on the mechanization level, quantity of active agricultural work and cultivable land [5, 6].

Energy demand in agriculture can be divided on the basis of source of energy i.e. direct and indirect energy. Direct energy inputs include those quantities that are consumed during the crop production period such as human, animal, fuel wood, agricultural waste, petrol, diesel and electricity; whereas, indirect energy use refers to the energy embodied in all the input factors that are to be consumed in a production system and it includes machinery, fertilizers, herbicides, pesticides and material for plant propagation [7]. It has been estimated that fuel and fertilizers, in particular nitrogen, amount more than 60% of all the consumables embodied energy [8, 9]. The energy input-output analysis is usually made to evaluate the efficiency and environmental impacts of production systems. This analysis will determine how efficiently the energy is used. Calculating energy input in agricultural production is more difficult in comparison to the industry sector due to the high number of factors affecting agricultural production [10].

The study on effect of farm size on energy use and input costs for cotton production was conducted in Turkey and it was found that large farms were more successful in energy productivity, energy use efficiency and economic performance. They were also concluded that energy management at farm level could be improved to give more efficient and economic use of energy [11]. Another study [12] concluded that the dry apricot production in different farm sizes in terms of energy use efficiency and economic analysis. They reported that, both the total energy input and output energy in apricot production decreased when farm size increased; while, the energy use efficiency and energy productivity increased when farm size increased. [13] investigated the energy consumption in small, medium and large farms of tomato production; they concluded that large farms were more successful in terms of energy use and economic performance.

The effect of farm size on energy ratio for wheat production and concluded that better energy efficiency and productivity were found on the large farms [14]. In addition, Technical efficiency (weighted output energy to weighted input energy ratio) is another way to explain the efficiency of farms [15]. The energy efficiency and cost analysis of canola production in different farm sizes. The results revealed that total energy input for canola production increased from small farms to large farms; while, the highest yield value was obtained from medium farms [16]. Besides these, still there limited study has been found on effect of size of land holdings on energy use in soybean productions was done. Therefore, the main objective of this study was to compare the energy use and energy indices for soybean production under different farmer's categories in Malwa plateau of India. It also identifies operations where energy savings could be realized by changing applied practices in order to increase the energy use efficiency and propose improvements to reduce energy consumption for soybean production.

II. Materials and Methods

A preliminary survey was conducted in different villages to investigate the pattern of energy utilization for soybean production during 2011-12 of Malwa Plateau Zone. The soils of the zone are too deep having slight to moderate erosion and the major crops are Soybean, sorghum and maize for Kharif (May–October) season. For the analysis of energy use in different farmers category, the selected farmers were classified into four groups of marginal (less than 1 ha), small (1 to 2 ha), medium (2 to 4 ha) and large (more than 4 ha). A stratified random sampling procedure was adopted to find the sample size [17].

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

Where n is the required sample size; N is the number of total holdings in the target population; N_h is the number of the population in the h stratification; S_h is the standard deviation in the h stratification, S_h^2 is the variance in the h stratification, D^2 is equal to d^2/z^2; d is the precision, where 5% is permissible error and z is the reliability coefficient (1.96, which represents 95% reliability). Thus, calculated sample size in this study was 128.

The source wise energy inputs used for soybean production including human power, animal power, diesel fuel, electricity, seeds, farm yard manure, fertilizers, chemicals and machinery were determined per hectare. In order to determine output and input energy, multiplying the physical quantities of output and input with their energy conversion factors gave the energy equivalents in MJ per hectare unit. Energy output arises mainly from the product and by-products. Energy output from main products is calculated by multiplying production and their corresponding energy equivalent. In calculation of energy output from by-product of the soybean, its straw weight was assumed to be equal to the weight of grain. The energy values were calculated by transforming data using energy equivalents shown in Table 1.

The energetic efficiency of the agricultural systems was calculated by the relation between energy inputs and output. Based on the energy equivalents of inputs and outputs, the indices of energy use efficiency, energy productivity, specific energy and net energy were calculated using the following equations [14]

Energy ratio = (Energy output) / (Energy input)

Specific energy = (Energy input (MJ/ha)) / (Grain output (kg/ha))

Energy productivity = (Grain output (kg/ha)) / (Energy input (MJ/ha))

Net energy = Energy output - Energy input

Energy use efficiency is defined as the ratio between the caloric heat of the output products and the total sequestered energy in the production factors. Energy productivity is the amount of a product obtained per unit of input energy. Energy output and net energy are crucial parameters when the availability of arable land is the limiting factor for plant production [18].

Table I Energy equivalents of inputs and output in soybean production

Energy sources	Units	Equivalent energy (MJ/unit)	Reference
Inputs			
Human			
Man	h	1.96	[19,20]
Woman	h	1.57	[19,20,21]
Animal-pair (Body weight 350–450 kg)	h	10.10	[19,20,21]
Machinery	h	64.8	[21,22]
Diesel	l	56.31	[19,20,22]
Petrol	l	48.20	[19]
Fertilizers			
Nitrogen (N)	kg	60.60	[19,23]
Phosphorus (P2O5)	kg	11.1	[19,23]
Potassium (K2O)	kg	6.7	[19,23]
Farm Yard Manure	kg	0.3	[20,24]
Electricity	kWh	11.93	[21,24]
Chemicals			
Superior (need dilution at the time of application)	l	120	[21,22]
Inferior (not need dilution)	kg	10	[21,22]
Output			
Soybean	kg	14.7	[6,19,21]
Straw	kg	12.5	[19]

III. Results and Discussion

A. Operation wise energy consumption

Table 2 represents the amount of input and output for soybean production in different farmers category. From the study it was observed that the operation wise energy requirement varied from 4181 to 4961 MJ/ha with mean value of 4575 MJ/ha. The minimum energy consumption was observed for marginal farmers (4181 MJ/ha) compared to small farmers (4380 MJ/ha), medium farmers (4775 MJ/ha) and large farmers (4961 MJ/ha) respectively.The higher energy expenditure by large farmers was mainly due to the use of larger machinery and tractor to performed different operations on their farms. Similar trend was observed for source wise energy consumed among different categories of farmers.

Figure 1 Operation wise and source wise energy use pattern for soybean production

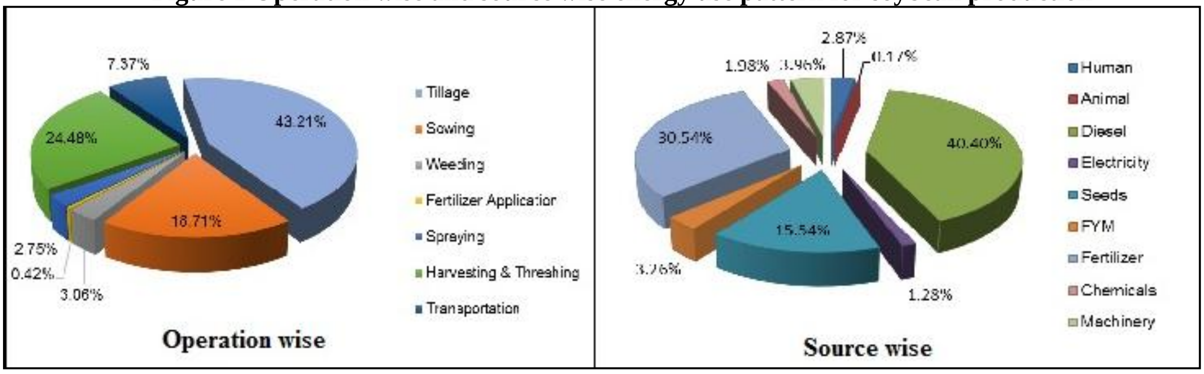


Fig.1 shows that energy required in tillage was maximum (43.21%) of total energy followed by harvesting & threshing (24.48%), sowing (18.71%), transportation (7.37%), weeding (3.06%), spraying (2.75%) and fertilizer application (0.42%). Higher energy use in tillage by large farmers was mainly due to the more number of operations required to prepare the field during summer season after harvesting of Rabi crops and due to the use of high horse power tractors. In weeding operation, energy used by the marginal and small farmers is high as compared to medium and large farmers. It was due to the manual weeding and use of bullock power for intercultural operation by marginal and small farmers. Weeding by medium and large farmers was manual as well as chemical resulting in more energy use in spraying by these categories of farmers. In the operation of fertilizer application energy consumed by marginal farmers is more and energy consumption is inversely proportional to farmers category. It is due the increased use of seed cum fertilizer drill by medium and large farmers, with use of seed cum fertilizer drill the operation of sowing and fertilizer application was combined in one operation.

Table II Operation wise and source wise input and output of soybean production

Operations/Sources	Farmers category				Weighted average
	MF	SF	MSF	LF	
Operation wise energy (MJ/ha)					
Tillage	1775	1891	2037	2203	1977
Sowing	792	821	894	918	856
Weeding	175	181	110	93	140
Fertilizer application	25	27	14	11	19
Spraying	87	74	158	183	126
Harvesting & Threshing	1013	1065	1184	1219	1120
Transportation	314	321	378	334	337
Total	4181	4380	4775	4961	4575
Source wise energy (MJ/ha)					
Human	297	305	221	195	255
Animal	28	32	0	0	15
Diesel	2837	3089	3861	4574	3590
Electricity	176	156	74	49	114
Seeds	1323	1296	1441	1463	1381
FYM	309	371	246	233	290
Fertilizer	2374	2393	2912	3177	2714
Chemicals	117	126	189	273	176
Machinery	288	326	373	421	352
Total energy	7749	8094	9317	10385	8887
Yield (kg/ha)	1278	1307	1443	1564	1398

B. Source wise energy consumption

Source wise energy requirements for raising soybean crop under different farmer's category in Malwa plateau are given in Table 2. It shows that the average energy input from different source was 8887 MJ/ha. The variation among the total energy input on the different categories of farmers was 7749-10385 MJ/ha. The total energy consumed by large farmers (10385 MJ/ha) was found to be higher followed by medium farmers (9317 MJ/ha), small (8094 MJ/ha) and marginal (7749 MJ/ha) respectively. Energy use per hectare was 34 % higher by large farmers and decreasing when the farm size group increased.

Fig. 1 shows that the maximum energy input was through diesel 3590 MJ/ha (40.40%). The diesel energy was mainly used for operating tractor and combine harvester. Diesel energy is followed by fertilizer 2714 MJ/ha (30.54%), seeds 1381 MJ/ha (15.54%), machinery 352 MJ/ha (3.96%), FYM 290 MJ/ha (3.26%), human 255 MJ/ha (2.87%), chemical 176 MJ/ha (1.98%), electricity 114 MJ/ha (1.28%) and animal 15 MJ/ha (0.17%). The yield of soybean was in the range of 1279-1565 kg/ha with mean value of 1398 kg/ha.

It was observed that when the land holding groups was increased from marginal to large farmers there was a decrease in the energy input value for human, animal, electricity and FYM while there was an increase for diesel, electricity, seeds, fertilizer, chemicals and machinery energy. Machinery energy consumed on farms of large farmers was around 46 % higher than marginal farmers and corresponding 22% increase in yield was observed**.** An increase in energy was mainly due to increased use of tractor driven implements, threshers and combine. It contributed to achieving higher productivity through timely completion of operations. Diesel and fertilizer energy was the biggest energy input for soybean production and account for more than 70 % of total input energy. With respect to the improving of energy efficiency, the diesel and fertilizer seemed to be the most significant categories for energy management.

C. Relationship between energy inputs and soybean yield

Fig 2 presents the effect of tillage energy, diesel energy, fertilizer energy and total input energy on yield of soybean. It is clear from the figure that the yield of soybean increases with input energy. The use of energy in tillage, diesel energy, fertilizer energy and total input energy by large farmers increased up to 2203 MJ/ha, 4574 MJ/ha, 3177 MJ/ha and 10385 MJ/ha respectively, corresponding increase in yield of soybean 1564 kg/ha was observed.

Considering input energy as predictor and yield as response following linear equation was derived:

Tillage energy, $\hat{y} = 0.7472\ x + 28.899$, (R2 = 0.7845)

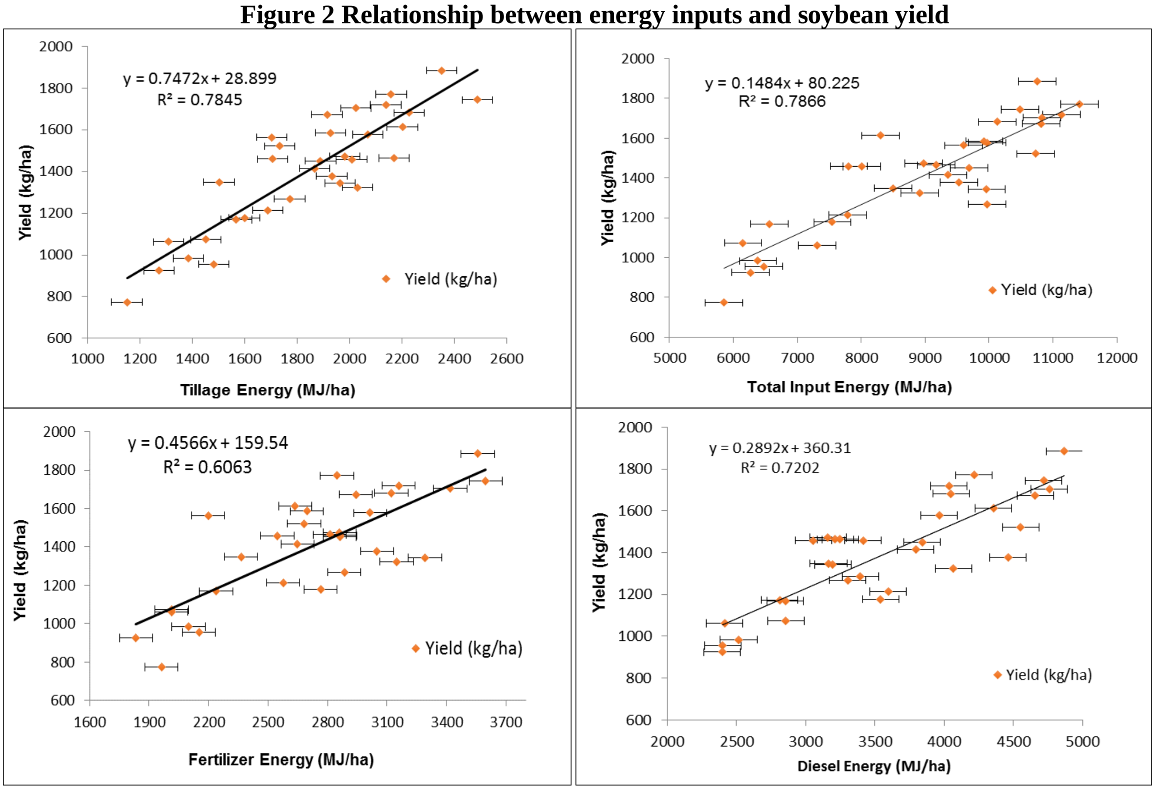
Diesel energy, $\hat{y} = 0.2892\ x + 360.31$, (R2=0.7202)

Fertilizer energy, $\hat{y} = 0.4566\ x + 159.24$, (R2=0.6023)

Total input energy, $\hat{y} = 0.1484\ x + 80.225$, (R2=0.7866)

Fig.2 further reveals that observed data are within the yield limit and has not reached to maximum limit, hence in the plateau there is a great scope to enhance yield by increasing additional input energy.

Figure 2 Relationship between energy inputs and soybean yield



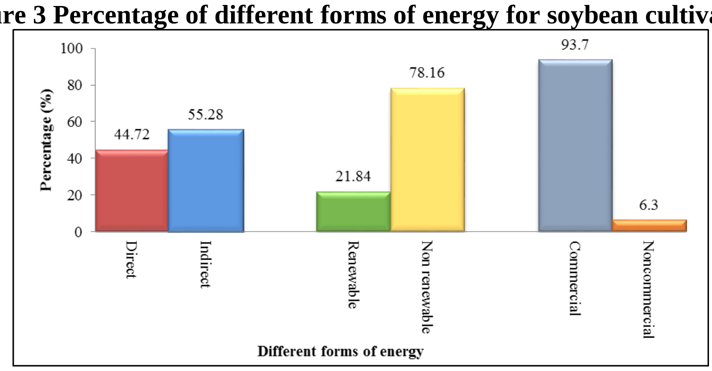
D. Effect of different size of land holdings on energy indices

The energy indicators for soybean production under different farmer's category are tabulated in Table 3. The results revealed that, soybean production in marginal farms showed the highest energy ratio as 4.49, while, energy ratio in large farms was the lowest as 4.01. An average of the energy ratio was determined as 4.28 and decreased as the size of land holdings increased and gave parallel results for energy productivity ranging from 0.150 kg/MJ on large farms to 0.165 kg/MJ on marginal farms. Specific energy in marginal farms was the lowest (6.06 MJ/kg) and it was highest in large farms (6.64 MJ/kg). With increase farm size the specific energy also increased. Moreover the large farms had the highest net energy (32156 MJ/ha).The total input energy use in the farms by marginal farmers and large farmers were 7749 MJ/ha and 10385 MJ/ha, the corresponding yield were 1278 kg/ha and 1564 kg/ha, respectively. According to the research results, energy was used more efficiently by the marginal farmers because they supervise their farms by themselves and manage all operation practices efficiently. The large farmers depend on labour to manage and supervision of farms. The increases in yield in large farms were due to additional physical inputs.

Table III Operation energy indices for different farmer's category for soybean cultivation

Indices	Unit	Farmers category				Weighted average
		MF	SF	MSF	LF	
Direct energy	MJ/ha	3338	3582	4156	4818	3974
Indirect energy	MJ/ha	4411	4512	5161	5567	4913
Renewable energy	MJ/ha	1957	2004	1908	1891	1941
Non-renewable energy	MJ/ha	5792	6090	7409	8494	6946
Commercial energy	MJ/ha	7115	7386	8850	9957	8327
Non-commercial energy	MJ/ha	634	708	467	428	560
energy ratio	-	4.49	4.39	4.21	4.01	4.28
Specific energy	MJ/kg	6.06	6.19	6.45	6.64	6.34
Energy productivity	Kg/MJ	0.165	0.161	0.155	0.15	0.158
Net energy	MJ/ha	27013	27456	29932	32156	29139

Figure 3 Percentage of different forms of energy for soybean cultivation



The distribution of inputs used in the production of soybean according to the direct, indirect, renewable, non-renewable, commercial and non-commercial energy forms for all of farmers groups are also given in Table 3. The results revealed that, in all of the farmers groups, the indirect energy was greater than that of direct energy. The share of direct input energy was 44.72% in the total energy compared to 55.28% for the indirect energy. The contribution of non-renewable energy forms was higher than that of renewable energy consumption. The research results shows that on average the renewable form of energy input were 21.84% compared to 78.16% for non-renewable energy. Commercial energy was much higher than that of non-commercial energy because diesel and fertilizer is account for more than 70% of source wise energy use. The commercial energy input was 93.70% compared to 6.30% for the non-commercial energy, (Fig. 3), that indicate that the current energy use pattern among the different size of farms is based on commercial energy for soybean production. Moreover, the ratio of direct and indirect energy resources were nearly the same, while, the renewable, non-renewable, commercial and non-commercial energies were fairly different from each other.

IV. Conclusions

This research was undertaken to evaluate the present energy use pattern for the most growing soybean crop of Malwa plateau of Madhya Pradesh. The data used in this research for the soybean production were collected from 128 farmers of Malwa plateau, where soybean is cultivated as one of the major crop. Soybean production consumed a total of 8887 MJ/ha energy, which is mainly from commercial sources. Energy use per hectare was increased when the farm size group increased, and it was 34% higher on large farms as compare to marginal farms. Diesel and fertilizer energy was the biggest energy input for soybean production and account for more than 70 % of total energy. The operational energy use varies between 4181 MJ/ha to 4961 MJ/ha from marginal to large farmers with mean value of 4575 MJ/ha. Among various field operations, seedbed preparation was observed to be maximum energy-consuming operation for soybean production under the different farmer's category. Seed bed preparation, sowing, harvesting and threshing were the main operations for energy consumption. Among the different categories of farmers, it was observed that better output–input energy ratio and energy productivity were found on the marginal farms. According to the result, marginal farmers were more successful in energy utilization.

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