An analysis of energy use efficiency of soybean production under different farming technologies

Seyed Hashem Mousavi-Avval*, Shahin Rafiee, Ali Jafari

Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

** Corresponding author. Tel: (+98) 2612801011 E-mail: sh.mousavi@ut.ac.ir*

Abstract: The main objective of this study was to examine the energy use pattern and energy productivity of soybean production under different farming technologies. Data for the production of soybean were collected from 94 randomly selected soybean farms from Golestan province, Iran, using a face to face questionnaire method. The population investigated was divided into two groups based on farm machinery ownership and level of farming technology. Group I farmers were 48 owners of agricultural machinery, practiced under high level of farming technology; whereas Group II were 46 non-owners of machinery, operating under low level of farming technology. The results revealed that 36726.48 MJ ha^{-1} energy consumed by Group I and 33955.27 MJ ha^{-1} energy consumed by Group II. Similarly, total energy output of soybean production was also higher in Group I than that of Group II (85757.28 vs. 77506.79 MJ ha^{-1}). The energy indicators were also investigated and the results showed that energy use efficiency of soybean production in Group I (2.34) was higher than that of Group II (2.28). From this study it was concluded that extension and education programs for the farmers are need to improve the efficiency of energy consumption in soybean production in the region.

Keywords: *Farming technology; Machinery ownership; Energy; Soybean production*

1. Introduction

Energy has a key role in economic and social development but there is a general lack of rural energy development policies that focus on agriculture. Agriculture has a dual role as user and supplier of energy [1]. In agriculture, a wide range of modern and traditional energy forms are used directly on the farm, e.g. as tractor or machinery fuel, and in water pumping, irrigation and crop drying, and indirectly for fertilizers and pesticides. Other energy inputs are required for post harvest processing in food production, packaging, storage, transportation and cooking [1]. Energy consumption in agriculture has developed in response to rising population in around the world, limited supply of arable land, and desire for higher standards of living [2].
Energy use is one of the key indicators for developing more sustainable agricultural practices. Wider use of renewable energy sources, increase in energy supply and efficiency of energy use can make a valuable contribution to meeting sustainable energy development targets [3]. Effective use of energy in agriculture is important for the evaluation of the environmental impact of production systems [4]. It is important, therefore, to analyze cropping systems in energy terms and to evaluate alternative solutions. Many researchers have studied energy and economic analysis to determine the energy efficiency of plant production such as sugarcane in Morocco [5], rice in Malaysia [6], pear production in China [4], onion production in Pennsylvania [7], sunflower production in Greece [8] and winter oilseed rape in Germany [9]. Moreover, comparing the medium and low levels of farming technologies in energy use efficiency point of view, Asakereh et al. [10] reported that the average input and output energies of apple production increased in parallel to the mechanization scale of farms; while, energy use efficiency decreased with increasing the level of mechanization. Also, Nandal and Rai [11] conducted a study by dividing Haryana in three homogenous zones on the basis of intensity of mechanization. In all, 54 farms were selected from each of the three zones making a total sample of 162 farming households. The impact of mechanization on crop yield was studied on three different categories of farms. It was apparent from the study that the tractor-

operated farms had higher yield of wheat and paddy. In case of farms using tractors on custom - hire basis, the yield was comparatively low. Their study also revealed that tractor-owing farms invariably used higher level of agricultural inputs and had better control on timeliness of operations.

Based on the literature there was no study on the relationship between farming technology and energy use efficiency of soybean production in Iran. Therefore, the main objectives of the present study were to estimate the energy inputs and output for soybean production under different farming technologies.

2. Materials and method

This study was conducted in Golestan province of Iran. Data on soybean production was collected from the farmers by using a face to face questionnaire method performed in 2010. Farms were randomly chosen from the villages in the area of study. For sampling, the simple random sampling method was applied; so the sample size was calculated as 94 and then the 94 farms from the population were randomly selected. The population investigated was divided into two groups. Group I was consisted of 48 farmers (owner of machinery) and Group II of 46 farmers (non-owner of machinery).

The energy analysis conducted in this study was aimed at estimating the difference in total energy inputs and outputs for soybean production under different farming technologies. The inputs were in the form of chemicals, chemical fertilizers, farmyard manure (FYM), diesel fuel, electricity, water for irrigation, human labor and machine power. The data was then transformed into energy terms (MJ ha^{-1}) by applying the appropriate conversion factors.

Following the calculation of energy input and output equivalents, to assess the energy efficiency of soybean production the indices of energy consumption including energy use efficiency, energy productivity, specific energy (energy intensity) and net energy were calculated as follow [12]:

$$Energy\ use\ efficiency = \frac{Energy\ output\ (MJ\ ha^{-1})}{Energy\ input\ (MJ\ ha^{-1})} \quad (1)$$

$$Energy\ productivity = \frac{Soybean\ yield\ (kg\,ha^{-1})}{Energy\ input\,(MJ\ ha^{-1})} \quad (2)$$

$$Specific\ energy = \frac{Energy\ input\,(MJ\ ha^{-1})}{Soybean\ yield\ (kg\,ha^{-1})} \quad (3)$$

$$Net\ energy = Energy\ output\ (MJ\ ha^{-1}) - Energy\ input\ (MJ\ ha^{-1}) \quad (4)$$

The energy inputs were divided into direct and indirect and renewable and non-renewable energy forms [13]. Direct energy consisted of human labor, diesel fuel and electricity; whereas, indirect energy included machinery, chemical fertilizers, farmyard manure, biocides and seeds. On the other hand, renewable energy consists of human labor, farmyard manure and seeds and non-renewable energy includes machinery, diesel fuel, chemical fertilizers, biocides and electricity.

3. Results and discussion

The amount of inputs used in soybean production and output for Group I and II of soybean producers are presented in Table 1. In the study region, the use of human power and machinery, respectively, were found to be 181.58 and 15.51 h ha^{-1}, in the farms with high level of technology and 207.90 and 13.19 h ha^{-1}, in the farms with low level of technology. Also the use of chemicals, chemical fertilizers and farmyard manure by Group I was higher than those by Group II; while Group II used higher water for irrigation. On the other hand the yield value of soybean was found to be 3430.29 and 3100.27 kg ha^{-1} for Group I and Group II, respectively. Rao [14] conducted a study to investigate the effect of use of tractors on yield. The results revealed that, of all the crops raised on different sizes of farms, tractor owning farms obtained higher yields.

Table 1. Amounts of inputs and outputs for soybean production under different farming technologies.

Item	Group I	Group II
A. Inputs		
1. Human labor (h)	181.58	207.90
2. Machinery (h)	15.51	13.19
a. Tractor	13.95	11.80
b. Combine harvester	1.56	1.39
3. Diesel fuel (L)	109.74	97.26
4. Chemicals (kg)	5.41	5.25
a. Herbicides	2.70	2.59
b. Insecticides	2.71	2.66
5. Chemical fertilizer (kg)	167.48	147.87
a. Nitrogen	100.90	88.79
b. Phosphate (P2O5)	57.02	43.56
c. Potassium (K2O)	7.03	11.41
d. Sulphur (S)	2.53	4.11
6. FYM	6309.71	4344.20
7. Water for irrigation (m3)	3261.18	3346.55
8. Electricity (kWh)	1362.47	1308.26
9. Seed (kg)	67.71	69.95
B. Output		
1. Soybean yield (kg)	3430.29	3100.27

Energy equivalents of inputs and outputs were calculated using the conversion factors of machinery and diesel fuel [15], human labor, chemical fertilizers, FYM and water for irrigation [15], chemicals [16], electricity [12], soybean seed and output [13]. The results presented in Table 2. It is evident that, Group I used higher machinery and consequently diesel fuel energy. Asakereh et al. [10] investigated the effect of mechanization level on energy use efficiency of apple production. They reported that farms with higher level of mechanization consumed higher machinery and diesel fuel energies. From the results of this study it is evident that, chemicals energy was used as 917.14 and 885.20 MJ ha^{-1} by Group I and Group II, respectively. Moreover, total energy input in Group I was 36726.48 MJ ha^{-1}; while it was only 33955.27 MJ ha^{-1} in Group II. Total energy output for soybean production under different farming technologies is also illustrated in Table 2. It was found to be 85757.28 and 77506.79 MJ ha^{-1} for Group I and Group II, respectively. Also, average energy output was found to be 85556.96 MJ ha^{-1}.

Table 2. Energy inputs and outputs for soybean production under different farming technologies.

Item	Group I (MJ ha^{-1})	Group II (MJ ha^{-1})
A. Inputs		
1. Human labor	355.90	407.48
2. Machinery	1026.56	890.99
3. Diesel fuel	5245.77	4649.21
4. Chemicals	917.14	885.20
5. Chemical fertilizer	7463.82	6546.37
6. FYM	1892.91	1303.26
7. Water for irrigation	3326.41	3413.48
8. Electricity	16254.22	15607.49
9. Planted seed	243.75	251.80
Total energy input	36726.48	33955.27
B. Output		
1. Total energy output	85757.28	77506.79

The results of energy analysis also show that in both the groups, the highest share of energy was consumed by electricity, chemical fertilizer and diesel fuel inputs. Moreover, the contributions of human labor and seed energies from total energy input were found to be relatively low. Similar studies had also reported that fertilizer and diesel fuel were the most intensive energy inputs [16,17].

The high contribution of electrical energy was mainly due to high water application in irrigation operations and also low energy use efficiency of water lifting systems. The improper use of groundwater in agricultural practices may result in land quality degradation such as soil erosion and reduction of organic matter. The high water input in soybean farms may exacerbate the problem of soil drainage and excessive leaching of water to shallow groundwater aquifers which may impact groundwater table and soil salinity dynamics [18].

Moreover, excessive use of chemical fertilizers energies in agricultural productions may create environmental problems such as nitrogen loading in the environment and receiving waters, poor water quality, carbon emissions and contamination of the food chain [18]. Improving timing, amount and reliability of water application and improving energy conversion efficiency of water pumping systems may help to reduce water application and consequently electrical energy consumption in the region. Application of composts, chopped residues or other soil amendments may increases soil organic matter content and fertility and so reduces chemical fertilizer requirement for crop production. Moreover, employing the technological upgrade to substitute fossil fuels with renewable energy sources, applying a better machinery management technique and employing the conservation tillage methods are suggested to reduce the fossil fuel usage and to reduce the environmental impacts.

Energy indicators for soybean production under different farming technologies are presented in Table 3. As it is seen, energy use efficiency was calculated 2.34 and 2.28 in the farms with high and low level of technologies, respectively. Also, energy productivity in Group I and Group II was calculated as 0.092 kg MJ^{-1}. Calculation of energy productivity rate is well documented in the literature such as 1.0 for stake-tomato [19], 0.20 for cotton [20] and 1.53 for sugar beet [16]. The specific energy of soybean production in Group I and Group II was 10.71 and 10.95 MJ kg^{-1}, respectively. Canakci et al. reported similar values for specific energy such as 5.24 for wheat, 11.24 for cotton, 3.88 for maize, 16.21 for sesame, 1.14 for tomato, 0.98 for melon and 0.97 for water-melon [21]. The net energy in Group I and Group II was 49030.79 and 43551.52 MJ ha^{-1}. The lower value for the net energy in soybean production in Group II has several reasons. Based on the structure of farming system and the level of technology in this group, such as using diesel fuel for water pumping systems, employing the traditional irrigation systems or wasting chemical fertilizers, the lower net energy is reasonable. Asakereh et al. reported that net energy gain of apple production under low level of farming technology was lower than that in high level of farming technology [10].

Table 3. Some energy indices for soybean production in Iran.

Item	Unit	Group I	Group II
Energy ratio	-	2.34	2.28
Energy productivity	kg MJ^{-1}	0.09	0.09
Specific energy	MJ kg^{-1}	10.71	10.95
Net E.	MJ ha^{-1}	49030.79	43551.52
Direct energy[a]	MJ ha^{-1}	25182.30	24077.65
Indirect energy[b]	MJ ha^{-1}	11544.18	9877.62
Renewable energy[c]	MJ ha^{-1}	5818.97	5376.02
Non-renewable energy[d]	MJ ha^{-1}	30907.51	28579.25
Total energy input	MJ ha^{-1}	36726.48	33955.27

[a] Includes electricity, human labor, diesel fuel, water for irrigation.
[b] Includes machinery, chemicals, chemical fertilizer, FYM, seed.
[c] Includes human labor, FYM, water for irrigation, seed.
[d] Includes diesel fuel, electricity, chemicals, chemical fertilizer, machinery.

The distribution of energy inputs used in the production of soybean according to the direct, indirect, renewable and non-renewable forms for all of farm groups are also given in Table 3. Also, the associated percentages are depicted in Fig. 1. The results revealed that, in all of the farm groups, the rate of direct energy was greater than that of indirect energy and the contribution of non-renewable energy forms was higher than that of renewable energy consumption. Moreover, the ratios of renewable and non-renewable energies were fairly different from each other (about 16% vs. 84%).

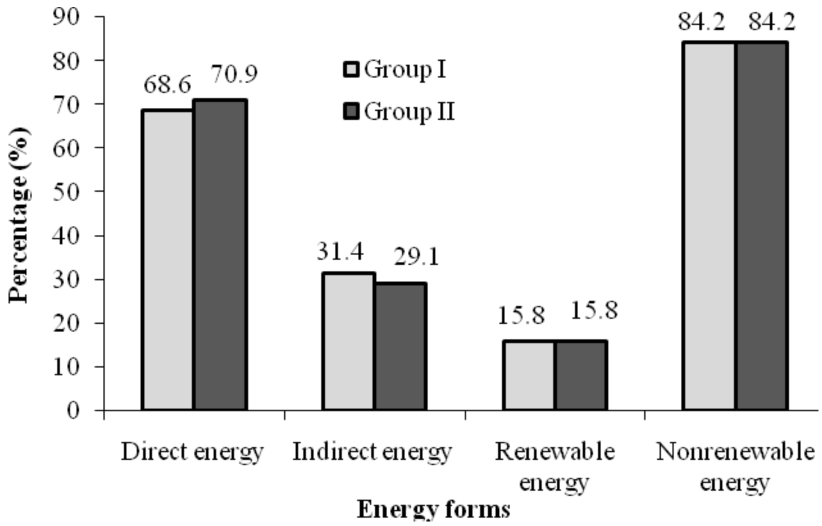

Fig. 1: Distribution of energy forms under different farming technologies

Totally, his study proposes strategies such as providing better extension services and farmer-training programs, including more educated people in soybean farming through provision of adequate facilities in order to increase energy use efficiency and to reduce the environmental impacts of food production in the region.

4. Conclusions

In this study the energy use efficiency of soybean production under different farming technologies was examined. Data used in this study were obtained from 94 randomly selected soybean farms in Golestan province, Iran. The population investigated was divided into two groups. Group I was consisted of 48 farmers (owner of machinery) and Group II of 46 farmers (non-owner of machinery). The results revealed that, the farms with high level of technologies had the higher energy input, energy output and energy use efficiency.

Energy management should be considered as an important issue in terms of sustainable, efficient and economic use of energy. Modification of operations, where possible, to make the best use of energy price structures, increasing the use of energy from renewable sources through application of composts, chopped residues or other soil amendments and also employing the conservation tillage methods would be useful not only for providing higher energy use efficiency and decreasing production costs, but also for reducing negative effects to the environment. The extension activities for the farmers in the region are needed to improve the efficiency of energy consumption in soybean production.

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