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Energy input-output and economic analysis for soybean production in Mazandaran province of Iran

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ABSTRACT

In this paper we examine the energy use patterns, energy input-output analysis and economic analysis of soybean production in Mazandaran province of Iran. The data were collected using a face-to-face questionnaire method from 95 farmers in Sari, Babolsar, Behshahr and Juibar counties. The results indicated that total energy input for soybean was about 38.7 $GJha^{-1}$. Among all inputs involved, electricity (49.42%) and fertilizer (20.82%) had the highest energy values per hectare. The benefit-cost ratio and energy ratio for cultivating for were found to be 1.56 and 2.06, respectively. Also, total cost of production was calculated 0.35 $\$kg^{-1}$ in the research area. The total mean expenditure for the production was 1145 $\$ha^{-1}$ that includes 969 $\$ha^{-1}$ for variable cost and 176 $\$ha^{-1}$ for fixed cost. Optimal consumptions of electricity and fertilizers as major inputs, minimum tillage and no tillage planting systems would be suggested.

Introduction

Soybean (Glycine max (L.) Merrill) is an annual legume and producing for edible oil and feeding livestock. Its crude protein content ranges from 41% to 50% (dry matter basis) (Liener 1994; Balat and Balat, 2010). The annual worldwide production of soybean grain is approximately 250 M t on 101.4 M ha and ranks first in the production of world oilseed crops (FAO, 2008). Soybean was produced about 209,000 t in Iran, and the harvested land area was about 115,000 ha in 2008 (Anonymous, 2010). In recent years soybean production in Iran has been improved specially in Golestan, Mazandaran and Ardebil provinces. Energy optimization and sustainable farming are main goals of the all developed countries. In developing nations, there is a higher amount of energy wastage. According to rising population and reducing source of energy in these countries, a long-term plan should be established to reduce wastage of energy. So effective use of energy in agriculture can be main way to help these countries towards development and prevent economical dependence to other nations. 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 (FAO, 2000). Energy input-output relationships in cropping systems vary with crops being grown in sequence, by type of soils, nature of tillage operations for seedbed preparation, nature and amount of organic manure, chemical fertilizer, plant protection measures, harvesting and threshing operations and, finally, yield levels (Mandal et al. 2002). Also, Energy input-output analysis in agricultural systems widely used in different cropping systems to find the efficiency and other energy and economic indices for several crops. Energy analyzing can be used as a first step towards identifying crop production processes that benefits most from increased efficiency (Mohammadi et al., 2008). The ratio of renewable energy including the energies of human power, seed and farm fertilizer inputs, within the total energy in all productions is very low. Renewable energy resources for example; solar, hydroelectric, biomass, wind, ocean and geothermal energy are sustainable and offer many environmental benefits over conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications (Miguez et al. 2006). In recent years, Data Envelopment Analysis (DEA) was employed as a non-parametric method and a major technique in productivity and efficiency analysis applied in different aspects of economics and management of agricultural units. Although within this context, several researchers have focused on determining efficiency in agricultural units, in different countries on crop cultivation, horticulture, aquaculture and animal husbandry for example: surveying the quantity of inefficient resources which are used in cotton production in Panjab in Pakistan (Shafq and Rehman, 2000), surveying energy use pattern analyses of greenhouse vegetable production (Canakci, and Akinc, 2006), surveying improving energy efficiency for garlic production (Samavatian et al. 2009), checking the efficiency and returning to the scale of rice farmers in four different areas of Panjab state in India by using (DEA) approach (Nassiri and Singh, 2010), and a case study in Turkey to analysis of energy uses for banana production (Akcaoz, 2010). In this study the aim is to investigate the energy use patterns, analyzes the energy input-output and finance indices in the cultivation of soybean in Mazandaran province of Iran.

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Materials and Methods

Study Region and Data Collection

This study was conducted in Mazandaran province of Iran. Mazandaran province is located in the north of Iran, within 31° 47' and 38° 05' north latitude and 50° 34' and 56° 14' east longitude. Data were collected through personal interview method in a specially designed schedule for this study. The collected data belonged to the 2011-2012 production year in August and September 2012. The size of each sample was determined by fallowing Equation (1) (Kizilaslan, 2009):

$$n = \frac{N(S \times T)^2}{(N-1)d + (S \times T)^2} \quad (1)$$

Where n is the required sample size; N is the number of holdings in target population; S is the standard deviation; T is the t-value at 95% confidence limit (1.96); and d is the acceptable error (permissible error 5%). Thus, 95 soybean farmers were selected for sampling. The soybean producers were surveyed in four regions namely; Sari, Behshahr, Babolsar, and Juibar. Also, choosing these counties was based on agricultural expert recommendation in Ministry of Jihad-e-Agriculture of Iran.

Energy Equivalents of Inputs and Output

In soybean production operations energy is used for; seedbed preparation, sowing, planting, fertilizing, weeding, irrigation, spraying, harvesting and transportation. In this study gathered data were included the quantity of eight energy inputs used per hectare of soybean production following: human power, machinery, diesel fuel, chemicals, fertilizer, water, seed and electricity, and the production yield as output. Human power (hha^{-1}) would use mainly for farm management, conducting some agricultural operations and tractor driving. Most of operations have been done by men. Machinery used for soybean production in this region is divided into 3 main groups; tractor, self-propelled combine and other machines. Other machines used contain moldboard plow, disk harrow, cultivator, planter, sprayer and trailer. All farmers owned tractor and Massey Ferguson 285 was the most popular tractor. Also, close to 80% of farmers, it means 72 farmer rent combine harvester for harvesting. The calculated energy for machinery will show all mechanical implements, transferring machines and other machines energy used for soybean production. To calculating the embodied energy in agricultural machinery it was assumed that the energy consumed for the production of the tractors and agricultural machinery is depreciated during their economic life time (Mousavi-Avval et al., 2011). Therefore, the machinery energy input was calculated using the Equation (2) (Gezer et al., 2003).

$$ME = \frac{G \times Mp \times t}{T} \quad (2)$$

Where ME is the machinery energy per unit area (MJha^{-1}); G is the machine mass (kg), Mp is the production energy of machine (MJkg^{-1}); t is the time that machine used per unit area (hha^{-1}) and T is the economic life time of machine (h). The diesel fuel energy requirement was determined according to fuel consumption, lha^{-1}. The following equation was used in the calculation of fuel consumption (Canakci, 2005):

$$FC = Pm \times R \times SFC \quad (3)$$

Where FC is the fuel consumption, 1ha^{-1}; Pm is the tractor power, kW; R is the loading ratio, decimal; and SFC is the specific fuel consumption (0.300 l kWha^{-1}). For calculating the fuel requirements of tractor and combine harvesters firstly, the fuel tank of the engine was completely filled before starting the field operation, then quantity of fuel required to fill the tank after performing the field test was measured using a 1L graduated cylinder. Thus, the fuel consumed during the test was determined (Canakci, 2005). The data were calculated for 1 hectare and converted into energy units and expressed in MJha^{-1}. The energy equivalents of inputs were used to calculate the input amounts are given in Table 1.

Table.1 Energy equivalences of inputs and outputs

Item	Units	Energy equivalent (MJ unit^{-1})	References
Input			
1. Diesel Fuel	L	47.80	(Kitani. 1999)
2. Electricity	kWh^{-1}	11.93	(Mohammadi and Omid 2010)
3. Human Power	h	1.96	(Rafiee et al., 2010)
4. Water	m^3	1.02	(Rafiee et al., 2010)
5. Machinery	kg		
Tractor		91.63	(Canakci et al., 2005)
Self-propelled combine		87.63	(Canakci et al., 2005)
Other machinery		62.70	(Canakci et al., 2005)
6. Fertilizer	kg		
Nitrogen		66.44	(Mohammadi and Omid. 2010)
Phosphate(P_2O_5)		12.44	(Mohammadi and Omid. 2010)
Potassium (K_2O)		11.15	(Mohammadi and Omid. 2010)
Farmyard manure		0.3	(Rafiee et al. 2010)
7. chemicals	kg		
Herbicides		238	(Rafiee et al., 2010)
Insecticides		101.2	(Rafiee et al., 2010)
8. Seed	kg	3.6	(BeheshtiTabar et al., 2010)
Output			
Soybean	kg	25	(BeheshtiTabar et al., 2010)

The energy efficiency, energy productivity, specific energy, net energy, benefit to cost ratio and productivity are defined by fallowed equations (Mohammadi and Omid, 2010, and Mousavi-avval and et al. 2011)

$$\text{Energy Efficiency} = \frac{\text{Energy output (MJha}^{-1})}{\text{Energy input (MJha}^{-1})} \quad (4)$$

$$\text{Energy Productivity} = \frac{\text{Soybean output (kgha}^{-1})}{\text{Energy input (MJha}^{-1})} \quad (5)$$

$$\text{Specific Energy} = \frac{\text{Energy input(MJha}^{-1})}{\text{Soybean Yield (kgha}^{-1})} \quad (6)$$

$$\text{Net energy} = \text{Energy output (MJha}^{-1}) - \text{Energy input (MJha}^{-1}) \quad (7)$$

$$\text{Benefit to Cost Ratio} = \frac{\text{Total Productin value (\$ha}^{-1})}{\text{Total Production value (\$ha}^{-1})} \quad (8)$$

$$\text{Productivity} = \frac{\text{soybean yield (kgha}^{-1})}{\text{Total Production cost (\$ha}^{-1})} \quad (9)$$

So, based on the energy equivalents of the inputs and output in Table 1 and recent equations these indices are calculated. The input energy indices in agriculture are divided into 4 group of energy; direct energy, indirect energy, renewable energy and non-renewable energy (Asakereh et al. 2010). The direct energy requirements are needed for land preparation, cultivation, irrigation, harvesting, post-harvest processing, food production, storage and the transport of agricultural inputs and outputs. Indirect energy needs are in the form of sequestered energy in fertilizers, herbicides, pesticides, and insecticides (FAO, 2000). So energy indices divided into fallowing groups (Abdi et al. 2012):

Direct energy: human power, diesel fuel, water and electricity
Indirect energy: chemicals, fertilizers, seeds and machinery
Renewable energy: human power, seeds and manure fertilizers
Non-renewable energy: diesel fuel, electricity, chemicals, water, fertilizers and machinery

RESULTS AND DISCUSSION

Energy Use Pattern

In this research, 95 similar farms with average farm size of 1.3, 1.8, 3 and 2.3 hectare in Sari, Behshahr, Banolsar, and Juibar respectively, were carried out. All of the agricultural machines were powered by tractor. On the other words, no animals were used for soybean production. The most popular soybean varieties in Mazandaran province are Sari, Telar and 033. Despite of high mean annual precipitation, 72% of farmers irrigate the farms by flooding irrigation system that led to water wastage and losses energy and lower yield; on the other hand 28% had pressurized irrigation system. Recent group harvest higher amount of soybean (about 5%) and save water, but they would pay fixed cost for irrigation system. The components of the energy use pattern for cultivating the soybean is shown in Table 2.

As it can be seen in Table 2, farmers in average used 93.7 kg nitrogen, 52.3 kg phosphate (P_2O_5), 8.1 kg potassium (K_2O), about 3.78 tons of farm yard manure, 2.3 kg herbicides and 2.3 kg insecticides per hectare. Amount of fertilizers and chemicals usage mainly depends on disease and insects attack in each county. Also, 194 h human power, 107.55 L diesel fuel, 3676.36 m^3 water and 1605.85 kWh electrical energy per hectare is used for the production of soybean in Mazandaran province. Optimum usage amount of diesel fuel shows two parameter; tractors in this region are modern rather than other region and machinery operations done with no time losses. In addition, the total machinery energy input for soybean production was 1164.5 $MJha^{-1}$. From related table, tractor sharing in total machinery is higher than other machinery. It can be explained that most of machinery operations, except harvesting farmers use tractor. On the other hand, about one third of farmers cultivate by minimum tillage and no tillage planting systems and their output were close to 2% higher than other farmers. To reducing fuel consumption, operator and machinery usage minimum tillage and no tillage systems can be useful for farmers, so improving these systems is suggested. Also to reduce water wastage, for both irrigation systems land leveling before planting is suggested. Diesel fuel used for; pumping water on farms with diesel water pump irrigating system, operating tractor and combine harvester. High amount of farmyard manure usage is caused by manure low cost.

Table 3 represents the average soybean output for each region. The average soybean output was found to be 3196.08 $kgha^{-1}$ ranged from 2808 $kgha^{-1}$ to 3584 $kgha^{-1}$ for 95 farmers in surveying counties. The energy equivalent of this is calculated as 79902.21$MJha^{-1}$. The farmers in Babolsar County had the best practices. In similar researches mousavi-avval et al. (2011) and Moraditochaee (2012) determined soybean yield 3233.15 $kgha^{-1}$ and 2377 $kgha^{-1}$ in Golestan and Guilan provinces of Iran, respectively. Better yield in Mazandaran province was mainly due to good inputs management and using best seeds varieties rather than other regions in Iran. Also crop rotations, soil type and residue management were effective factors for better soybean yield. The basic pattern for crop rotation in Mazandaran province is wheat-soybean but, many farmers use canola-soybean in their cropping system. Finally, the energy used in the production of soybean consists of 2.08% chemicals, 0.98% human power, 0.67% seed, 3.25% machinery, 20.82% fertilizers, 13.3% diesel fuel, 49.42% electricity and 9.93% water inputs. The highest energy input is provided by electricity. The high amount of electricity energy in this region is mainly due to use electrical motor for pumping irrigation water. The distribution of inputs used in soybean production illustrated in Figure 1.

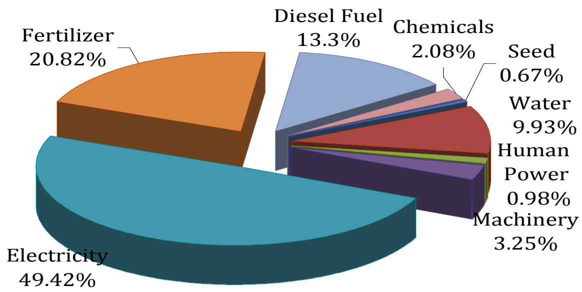

Fig1.The distribution of inputs used in the production of soybean

Mousavi-avval and et al. (2011) reported that for producing soybean in Golestan province of iran the total energy input was about 35372 $MJha^{-1}$, that the highest share was consumed by electrical energy, followed by fertilizers and diesel fuel inputs. In similar research Moraditochaee (2012) reported diesel fuel and nitrogen had the highest share for producing soybean in Guilan province of Iran. Also Dehshiri and Aghaalikhani (2012) revealed that soybean production in the main cultivation areas in Iran consumed a total of 29895.49 $MJha^{-1}$of which the share of diesel fuel and chemical fertilizer. Mobtaker et al. (2011) applied a parametric method to establish relationship between the yield and total energy input for alfalfa production in Iran. Their result showed that the total energy input for various processes in the alfalfa production was calculated to be 810.57 $GJha^{-1}$ and machinery energy was the most significant input affecting the output level. Omid et al. (2011) concluded that the input energy for cucumber production was to be 152908 $MJha^{-1}$ and the average inputs energy consumption was highest for diesel fuel, total chemical fertilizer and electricity. Yilmaz et al. (2005) found that fertilizers and machinery energy consumption of cotton production was high. Pervanchon et al. (2002) found machinery and fertilizers inputs as highest energy consumer in potato production with share of 48% and 33%, respectively.

Energy Indices in Soybean Production

Main calculated energy indices including energy ratio, energy productivity, specific energy and net energy gain, as well as the distributions of inputs according to the direct, indirect, renewable and non-renewable energy groups are given in Table 4. Within 95 enterprises that were analyzed, the share of non-renewable energy for soybean production was 95.41%.

Table 2. Amounts of inputs, output and their energy equivalents for soybean production

Input	Quantity per unit area (Unit ha^{-1})	Total energy equivalent (MJ ha^{-1})	Percentage
Diesel Fuel (L)	107.55	5161.0	13.3
Electricity (kWh)	1605.85	19157.78	49.4
Human Power (h)	194	381.01	1.0
Water (m^3)	3676.36	3749.89	9.6
Machinery (h)		1164.5	3.0
Tractor	16.82	472.5	1.2
Self-propelled combine	1.5	395.9	1.0
Other machinery	14.2	295.76	0.7
Fertilizer (kg)		8079.31	20.8
Nitrogen	93.75	6201.22	16.0
Phosphate (P_2O_5)	52.32	650.9	1.6
Potassium (K_2O)	8.17	91.13	0.2
Farmyard manure	3785.9	1135.78	2.9
chemical(kg)		808.93	2.1
Herbicides	2.380	566.59	1.4
Insecticides	2.39	242.23	0.6
Seed (kg)	72.13	259.69	0.6
Total energy input		38756.32	100

Table 3. Soybean yield in the four study regions

county	Average soybean yield (kg)	Total energy equivalent(MJ ha^{-1})
Sari	3140.5	78512.5
Behshahr	3045.6	76140
Babolsar	3245.7	81142.5
Juibar	3130.2	77825
Total	3196.08	79902.21

a human power, diesel fuel, water for irrigation and electricity
b the chemicals, fertilizers, seeds and machinery
c human power, seeds and manure fertilizers
d diesel fuel, electricity, chemicals, water, fertilizers and machinery

Table 5. Economic indices for soybean production in 2011/2012 growing season

Cost and return components	Unit	Value
Yield	$kgha^{-1}$	3196.08
Sale price	$\$kg^{-1}$	0.56
Gross value of production	$\$ha^{-1}$	1789.8
Variable cost of production	$\$ha^{-1}$	969
Fixed cost of production	$\$ha^{-1}$	176
Total cost of production	$\$ha^{-1}$	1145
Total cost of production	$\$kg^{-1}$	0.358
Gross return	$\$ha^{-1}$	820
Net return	$\$ha^{-1}$	644
Benefit to cost ratio	-	1.56
Productivity	$kg\$^{-1}$	2.79

Dehshiri and Aghaalikhani (2012), Moraditochaee (2012) in their study on soybean production in Iran found similar results, that the share of non-renewable energy is higher than renewable energy consumption. The energy ratio in Table 3 was calculated as 2.06 for soybean production. It reveals that output energy of soybean is obtained about 2 times greater than total energy input. Mousavi-avval et al. (2011) and Moraditochaee (2012) reported energy ratios for producing canola and soybean were 3.02 and 4.32, respectively. Likewise, this value for maize production in turkey recorded 3.6 (Yilmaz, 2005) for Iranian kiwifruit and alfalfa were 1.58 (Mohammadeti et al., 2010), and 4.83 (Yousefi and Mohammadi, 2011), respectively. The use of renewable energy in Mazandaran is very low. It shows that soybean production depends on non-renewable energy and mainly electricity. So deposit of rising electricity price optimum usage of electricity is necessary. Cost energy ratio can be increased by raising the crop yield, optimal usage of inputs and improving renewable energy consumption. Although, timing of any operations and use of the inputs is not significant issue, it is an important factor to reducing energy consumption. Therefore, there is a need to develop a new policy to encourage farmers to on time planting. Fortunately, in recent years soybean yield has increased, but still farmers use intensive farming system in Mazandaran province and consume high amount of inputs. Therefore, to prevent environmental problems, soil destruction and energy wastage, optimization usage of inputs for all farmers in these regions is recommended.

Finance Analysis of Soybean Production

The total expenditure in soybean production is categorized into two groups; fixed costs and variable costs. Tractor, Combine harvester and other machinery costs for farmers who rent machinery, are considered as one of the variable expenditures indexes. Also, the land rental cost calculated as fixed cost. Variable costs related to inputs costs in this studied growing season. Also for owner farmers, farm and machinery opportunity cost had been calculated as fixed cost. Economic indices are given in Table 5. Family labor cost was equalized with hired labor cost. Machinery operation costs were considered as operator, fuel, lubrication and repayments costs. Overhead costs which included; depreciation, investment in machinery interest, taxes, insurance and housing were calculated. In addition, lubrication cost was considered as15% of the total fuel cost. Fixed costs and variable costs are expressed in US currency (US$).

As it can be seen from Table 5, the costs of each input and gross production values for soybean production are given. By multiplying the soybean yield (3196.08 $kgha^{-1}$) by soybean price (0.56 $\$kg^{-1}$) the gross value of production (1789.8 $\$ha^{-1}$) was found. Babolsar region farmers (1817.59 $\$ha^{-1}$) and Behshahr region farmers (1705.53 $\$ha^{-1}$) had the highest and the lowest production gross value, respectively. The total mean expenditure for the production was 1145 $\$ha^{-1}$. About 85% of the total expenditures were variable costs, whereas 15% was fixed costs. In fact, 969 $\$ha^{-1}$ and 176 $\$ha^{-1}$ were spent for variable cost and fixed cost, respectively. Other studies reported that the ratio of variable cost was higher than that for fixed cost in cropping systems (Cetin and Vardar, 2008; Mohammadi and Omid, 2010, Esengun et al. 2007). Nevertheless, 15% of total cost allocated to fixed cost can be explained that agricultural farm price and rental price in Mazandaran province is high and it's due to good farming conditions (soil and precipitation). From Table 5, it can be seen the benefit-cost ratio for soybean production in these regions was 1.56. These results were consistent with the similar studies as 1.83 and 2.21 for greenhouse and open field grape (Ozkan et al. 2007), 1.35 for soybean (Dehshiri and Aghaalikhani, 2012) and 1.36 for garlic production (Samavatian et al. 2009). To finding gross return (820 $\$ha^{-1}$), the variable cost of production per hectare was subtracted from the gross value of production. Finally, the productivity (2.79 $kg\$^{-1}$), was obtained by dividing soybean yield by total production costs. Results from economic analysis of soybean production showed that soybean farming in Mazandaran province is beneficial.

Conclusion

The total energy requirement for cultivating soybean was found to be 38756.32 $MJha^{-1}$. In energy sources, electricity, fertilizer and diesel fuel had the maximum energy values. The values of the energy ratio for cultivating were 2.06. Also, the values of specific energy consumption for soybean cultivation were 12.12 $MJkg^{-1}$. In this research the ratio of renewable energy within the total energy is very low. The share of non-renewable energy was 4.58%. Using minimum tillage and no tillage planting systems in order to reducing energy consumption and soil compaction is suggested. Soybean farmers in Mazandaran province have good practice and their inputs management method can be suggested to improve the production of other soybean farmers in Iran.

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