Energy use pattern in production of sugar beet in western Azerbaijan province of Iran

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Abstract: With regard to the limitation of energy resources, especially non-renewable sources and the increasing trend of energy consumption in agriculture, energy management in this sector is important. The purpose of this study was to assess energy productivity, input and net energy output, and output-input energy ratio of sugar beet production in western Azerbaijan province of Iran. To achieve these objectives, statistical data about cultivation area, sugar beet yield in 2010 were acquired from the agricultural research center of west Azerbaijan province. Also, data about cultivation methods, implements and machinery in use were obtained from sugar beet farmers by questionnaire. According to the results, total energy consumption in sugar beet production was 52268.72 MJ ha^{-1}, output energy was 722400 MJ ha^{-1}, energy output-input ratio was 13.8, net energy was 670131.28 MJ ha^{-1} and energy productivity was 0.82 kg MJ^{-1}. The major energy consumers were chemical fertilizers with 34% of total input energy, irrigation (22%), implements and irrigation equipment manufacturing (12.84%) and spraying (6.98%), respectively. Approximately 29.58% of total input energy used in sugar beet production was direct energy and the remaining of 70.42% was indirect.

Keywords: sugar beet, energy, direct energy, energy ratio

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1 Introduction

During the whole history, human has always used different sources of energy to provide his basic requirements. Due to the factors, such as population growth, environmental issues, climate factors and the reduction of fossil fuel resources, the importance of energy use management has been highlighted. Nowadays the country’s development depends on having a complete and targeted plan to manage energy resources. During 1970s, investigations on energy consumption after energy crisis occurrence were passed. One of the sectors depended on energy was the agriculture provided world’s increasing population with enough food and offer food security.

Because of major similarity to natural ecosystems and the usage of human and animals as energy resources, traditional system lead to less energy costs as well as high energy efficiency. However, this system has a low yield and so can’t offer world’s growing population, especially in terms of food supplying. Thus traditional ecosystems have been replaced by intensive ecosystems which result in higher crop output due to the use of new technologies, fossil fuel, electricity, etc.

It is vital that energy analysis manages rare resources and enhance crop yield, which helps to identify competent and economical producing activities. It also helps to figure the consumed energy at each phase of the production process (i.e. denoting the phases requiring the least input energy), introduce a fundamental for the protection of resources as well as sustainable management and decision making (Chaudhary et al., 2006). Due to diversity of genetic resources, major

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natural and geographical resources in agricultural productions, agricultural sector is one of the crucial economic sectors in Iran. 90% of food need, 25% of employment, more than 20% of GDP and more than 15% of country's exports are provided by the agricultural sector which highlights the importance of this sector. With regard to the importance of non-petroleum exports and the skills of cultivating agricultural productions in different parts of the country, according to international standards to produce crops meeting is necessary. The growing trend in utilizing machines in agricultural operations and their costs make it vital to implement more studies to determine costs and the value of energy consumption to achieve an optimum utilization of machines, specify appropriate machines for various field conditions to reduce the energy costs.

In 2010, the area under sugar beet cultivation has been estimated to be around 99000 hectares in Iran. The western Azerbaijan province with the largest area under sugar beet cultivation accounted for 27.9% of the whole country's cultivated fields. The provinces of Khorasan Razavi, Fars, Kermanshah, Qazvin and Hamedan, respectively with 24.8%, 14.6%, 9%, 6.3% and 3.2% of the country's total sugar beet area, were in the second to sixth positions. These six provinces included 83.2% of sugar beet fields in the country.

Country's sugar beet production has been determined to be 4.1 million tons during the growing season of 2010. Western Azerbaijan province, with 33% of total national output has been ranked as the first sugar beet producer among the country's provinces and the provinces of Khorasan Razavi, Fars, Kermanshah, Qazvin and Hamedan respectively with 22.9%, 13.4%, 9.4%, 3.4% and 2.9% of the country's total sugar beet production, were in the second to sixth places. Generally 84.9% of the country's total sugar beet production is yielded in these six provinces. Sugar beet yield average in Iran is 43000 kg ha^{-1}. The highest and lowest yield in the country with 64559.1 and 26095.1 kg ha^{-1} respectively belongs to Kurdistan and Zanjan provinces (Anonymous, 2010). Input and output energy depends on various methods of agricultural practices, conditions and methods of production, crop type and how much the operations have been mechanized. There are different methods for calculating energy consumption in the scientific literature. Avlani et al. (1977) assessed energy consumption of agricultural companies, by surveying energy resources (such as oil derivatives, coal, natural gas and electricity) in California. Allen et al. (1980), Dowding et al. (1967) and Pervanchon et al. (2002) evaluated energy consumption in agricultural activities by measuring the draft of the tractor drawbar.

To assess the energy consumption of farming systems, an index has been introduced which was obtained by using two types of energy: non-direct energy (fertilizers and pesticides) and direct energy (machines and irrigation systems). Human energy that is used for agricultural work is assumed to be around 96.1 MJ hr^{-1} (54.0 kW). Energy which can be produced by human muscle is equal to 50-75 W. Additionally, energy produced by males equals 1.96 MJ hr^{-1}, by females 0.8-1.96 MJ hr^{-1} and by kids 0.5-1.96 MJ hr^{-1} (Keihani, 2006). Kalk et al. (1996) concluded that investigation of farming input and output energy are essential for energy balance in agriculture.

The input and output energy of Turkish agricultural sector within the years of 1995 and 2000 was examined by which the output energy for producing 104 kinds of agricultural products was evaluated (Ozkan et al., 2004). The product output was defined as a function of physical energy, fertilizer energy and seed energy. Results indicated that the total input energy increased from 19.6×10^9 J in 1995 to 45.7×10^9 J in 2000 and the total output energy increased from 27.1×10^9 J in 1995 to 34.1×10^9 J in 2000 and the energy indexes, specially the ratio of output to input energy and the net energy declined during the investigation period. The physical energy consists of labor, animal, agricultural implements and tractor, electricity and diesel energy. During the investigation, the total physical energy increased from 8800 MJ ha^{-1} to 12800 MJ ha^{-1} (12% of the total energy increment). Diesel energy magnitude rose from 2500 MJ to 5800 MJ per hectare (17.6% of total energy), human energy declined from 4100 MJ ha^{-1} to 3800 MJ ha^{-1} (11.6% of the total energy), animal energy decreased from 1400 MJ ha^{-1} to 1800 MJ ha^{-1} (4.3% of the total energy) and electricity energy rose from 300 MJ ha^{-1} to 1700 MJ ha^{-1} (5% of the total energy) (Ozkan et al., 2004).

The priorities of mechanizing the production of any crop are determined, according to the technical, economic and social aspects of the society. In this study sugar beet production of Miandoab and Nagadeh cities which are located at the north western of Iran were examined during the growing season of 2010. The objectives of this study are:

1. Comparing the performance and determining the magnitude of sugar beet energy consumption in the sugar beet fields of the Western Azerbaijan province.

2. Evaluating and specifying energy indexes (i.e. net energy output, energy ratio) and comparing them with other areas under sugar beet cultivation in Iran and the other countries

3. Determining the sugar beet energy consumption in terms of direct and indirect energy

2 Methods and materials

Miandoab is a city located in the southern part of the Western Azerbaijan province. Agriculture and horticulture form the basis of its economy. The city’s agricultural and horticultural crop yield consists of wheat, sugar beet, grapes, apple, pear and almond. The total arable land of this city is 820,000 m^2. 50 thousand hectares are irrigated and 32 thousand hectares are dryland. In the growing season of 2010 the total sugar beet cultivated land was 5219 hectares and the sugar beet yield were approximately 29×10^7 kg in Miandoab. The remaining lands were under the other crop cultivation.

Nagadeh is another city of the province. With 49500 hectares of arable land, this city accounts for 16% of the total production in the province. In the growing season of 2010, about 4500 hectares of the city’s land were under sugar beet cultivation. Because the objective of this study was to investigate the status of the region’s sugar beet fields, the best method is to use questionnaires and face to face interviews with the sugar beet growers. Cochran formula was used to find the number of samples. Cochran has offered the following formula to calculate the required sample size when using a random sampling method (Mansoorfar, 2008).

$$n = \frac{Nt^2S^2}{Nd^2 + t^2S^2} \tag{1}$$

where, *n*: the size of the sample; *N*: the size of the statistical population or the number of sugar beet growers; *t*: acceptable confidence which is obtained from the t-student table, assuming the desired characteristics to be in a normal distribution (1.96 at 95%); S^2: the variance estimation of the treated characteristic in the society (the variance of the energy ratio in the researched region was considered); *d:* the potential efficiency (half of the confidence interval).

To determine the population variance, 40 persons of the sugar beet growers and tractor drivers of the region were pre-tested randomly and the variance of the energy ratio was estimated. Then using Cochran formula and taking other variables into account, the size of the samples was calculated to be 10% of the society (i.e. 105 persons). After determining the statistical population and the number of the required samples, the final questionnaire was developed according to the objectives of the study, includes eleven major parts (Table 1).

Table 1 Main parts of developed questionnaire

Main Parts of questionnaire	
Owner information	1. Age, education; 2. Sugar beet cultivated area; 3. Cultivated Variety; 4. Average product price; 5. Soil texture; 6. Product cutie
Primary tillage	1. Plow type; 2. Plow working depth, width and speed; 3. Plow price; 4. Tractor type; 5. Working time in a hectare; 6. Driver education and his wage; 7. Fuel and oil used amount
Secondary tillage	1. Plow type; 2. Plow working depth, width and speed; 3. Plow price; 4. Tractor type; 5. Working time in a hectare; 6. Driver education and his wage; 7. Fuel and oil used amount
Field leveling	1. Leveler type; 2. Leveler price; 3. Leveler width, depth and speed; 4. Tractor type; 5. Working time in a hectare; 6. Driver education and his wage; 7. Fuel and oil used amount; 8. Driver education and his wage
Spraying	1. Spraying machine type and its price; 2. Value of used pesticide; 3. Pesticide price; 4. Type of tractor; 5. Working time in a hectare; 6. Driver education and his wage
Fertilizers	1. Fertilizing machine type and its price; 2. The amount of used fertilizer and its price; 3. Type of tractor; 4. Working time in a hectare; 5. Driver education and his wage
Planting	1. Planting machine type and its price; 2. Working width of the planter and the number of rows; 3. The amount of used seed in a hectare and its price; 4. Power transmission type of the planter; 5. Type of tractor; 6. Working time in a hectare; 7. Driver education and his wage
Irrigation	1. Irrigation method; 2. The amount of used water; 3. Water price; 4. Irrigation time over a specified period; 5. Used Power system type and its working time; 6. Labor wage
Plant protection	1. Method used for weeding; 2.Type of weeding Machine and its price; 3. Type of the tractor and its price; 4. Working time in a hectare; 5. Driver and labor wage
Harvesting	1. Type of harvesting machine; 2. Type of tractor used together with harvesting machine; 3. Width of harvesting machine and its speed; 4. Harvesting time in hectare; 5. Driver and labor wage
Product transportation	1. Type of used machine; 2. Machine and drive expenses in an hour; 3. Labor wage

Since one of the objectives of the study was to compute the magnitude of energy and energy ratio, information on agricultural operations, costs and performance had been obtained beforehand in order to specify and edit the wrong and illogical data when implementing the fieldwork research, so that the best and most relevant information could be obtained after statistical analysis. Some farmers and drivers education were less than we expected, hence their response was not reliable. Hence, obtained data from them was neglected and was not considered in the computation. Also, some data on fuel use was out of scientific range, therefore it was not considered. For this reason the number of questionnaire was 10% more than computed value.

In order to analyze the data from the questionnaire, first all the data and information relating to any sugar beet grower was entered into Excel Software on which required calculations took place, then the average of whole data was calculated and finally a completely randomized method and the LSD test (Least Significant Difference test) were used to analyze the data.

2.1 Evaluating energy consumption

Energy of machines (tractors), fossil fuels, irrigation, fertilizers, manure, seed, chemical pesticides, electricity, transportation and labor work could be noted as the energy inputs used in the production of most crops, including sugar beet. According to its equivalent energy based on the energy balance table, each imports some energy into the production system. It should be noted that sun's energy has not been regarded in this study and the consumed energy has been expressed in MJ ha^{-1}.

2.2 Energy of tractor and implements

To evaluate the input energy of machinery and equipment per hectare, it is crucial to assess machines weight, their working life span and the average field area they cover within a year (Ju et al., 2006). Equation (2) was used to compute mechanical energy.

$$E_{mech} = E_{tr} + E_{im} \tag{2}$$

$$E_{tr} = (W_{tr} \times EI_{tr}) / (n_{tr} \times Ca_{tr}) \tag{3}$$

$$E_{im} = (W_{im} \times EI_{im}) / (n_{im} \times Ca_{im}) \tag{4}$$

where, E_{mec}: total mechanical energy, MJ ha^{-1}; E_{tr}: the tractor energy, MJ ha^{-1}; E_{im}: the implement energy, MJ ha^{-1}; W_{im}, W_{tr}: weight of the tractor and implements, kg; EI: energy intensity, MJ kg^{-1}; n: the useful life span, hr; Ca: real capacity, ha hr^{-1}.

To evaluate real capacity the Equation (5) was used (Almasi et al., 2008):

$$C_a = \frac{A}{t} \tag{5}$$

where, A: the area in which the operation took place, ha; t: operation time, hr.

In order to calculate the magnitude of tractor and implement energy, the energy expended to manufacture the machine was supposed to be dissipated over its useful lifetime. Table 2 shows energy equivalents for tractors and a number of implements.

Table 2 Energy equivalents for tractors and a number of implements (Keitani, 1999)

Implements	Energy content, MJ kg^{-1}
Tractors	138
Plow	180
Rotavator	149
Disk	149
Planter	133
Fertilizer	129
Sprayer	129
Combines	116

2.3 Evaluating fuel energy

Fuel used in all tractors and most of the farming operations was diesel so the equivalent energy of diesel fuel was used to evaluate the energy. Diesel fuel heating value is 38.7 MJ L^{-1} and the average energy used for its production and transportation is 9.1 MJ L^{-1}, thus the total energy content is 47.8 MJ L^{-1} (Kitani, 1999). In this study, the fuel consumption per hectare value has been assessed based on the obtained information from the drivers and farmers. After determining the value of fuel consumption in each operation then adding them together, the total value of consumed fuel per hectare was calculated and finally using the reference values (Kitani, 1999) which represent the equivalent energy per liter of fuel in MJ L^{-1}, fuel energy was calculated using the following formula.

$$E_f = Q_f \times EI_f \tag{6}$$

where, E_f : fuel energy, MJ ha^{-1}; Q_f: the consumed value of fuel, L ha^{-1}; EI_f: the equivalent energy of fuel, MJ L^{-1}.

2.4 Energy for irrigation

Most of the farmers have no trouble in using channels and wells for irrigating in the research region. In addition, the majority of the water pumps used in wells and channels were of diesel type. Irrigation energy consists of the energy spent on digging wells, pumping equipment manufacturing, the consumed fuel or electricity energy for water transfer. In other words, both direct and indirect energy consumption in the irrigation operation were considered. Direct energy is the energy used for water pumping per hectare calculated according to Equation (7) (Kitani, 1999) which has been used to quantify the required electrical energy for irrigating. Equivalent energy for electricity is equal to 11.93 MJ KW^{-1} hr^{-1} (Singh et al., 2002).

$$DE = \frac{\gamma g H Q}{E_p E_q} \tag{7}$$

where, DE: irrigation direct energy, J ha^{-1}; γ: water density, 1000 kg m^{-3}; g: gravity acceleration, 9.8 m s^{-2}; Q: the total water discharge (water evaporation losses, water leakage and drainage in a growing season were considered), m^3 ha^{-1}; H: dynamic head of the well, m; E_P: pump efficiency usually equals to 70% to 90%; E_q: the electromotor efficiency equals to 18% to 22%.

The average of total consumed water for sugar beet cultivation was determined to be 9000 m^3 ha^{-1} and the equivalent energy for water energy consumed to be 1.02 MJ m^{-3} (Mohammadi and Nazarzadeh, 2006).

2.5 Seed energy of sugar beet

Regarding the used amount of seed per hectare in all samples (2 to 3 kg per hectare of the monogerm type) and the equivalent energy per kilogram of sugar beet seed, the seed input energy was estimated according to the following equation:

$$E_f = W_t \times E_i \tag{8}$$

where, E_f: the consumed energy of seed, MJ ha^{-1}; W_t: the amount of consumed seed, kg ha^{-1}; E_i: seed energy, which is 54 MJ kg^{-1} for sugar beet seed (Kitani, 1999).

2.6 Energy of fertilizers

In order to determine the input energy of fertilizers, first the amount of fertilizer per hectare was obtained by asking the farmers. Then the net percentage of each type of the fertilizer, which was written on their bags was multiplied by the amount of consumed fertilizer and the equivalent energy for producing per unit of fertilizer. The major energy consumption of fertilizer is related to its production, also the total amount of input energy includes packaging and transportation. According to available energy per kg of fertilizer and using the net consumption of fertilizers per hectare, the energy content of fertilizers was calculated as following (Kitani, 1999).

$$E_f = W_f \times EI_f \tag{9}$$

where, E_f: the energy of fertilizer, MJ ha^{-1}; W_f: the weight of the consumed fertilizer, kg ha^{-1}; EI_f: the equivalent energy of fertilizer, MJ kg^{-1}.

Chemical fertilizers contain both direct and indirect energy. Direct energy is due to the fuel used for tractor and indirect energy is due to the energy needed for manufacturing the tractor and fertilizer spreader or the manpower needed for the fertilizer spreading. Chemical fertilizers used to supply minerals needed by plants is urea fertilizer with 46% of pure nitrogen which is offered to the plants in liquid form mixed with the irrigation water or as urea fertilizer usually after plant emergence, within some stages of plant growing in spraying form. Di Ammonium Phosphate fertilizer with 18% of nitrogen and 23% of pure phosphor or 46% of complete phosphor (P2O5) was given to the ground before planting. The field was offered with potassium sulfate fertilizer with 48 percent of potassium. Table 3 shows different type of fertilizers and their energy was used for sugar beet production.

Table 3 Average energy of used fertilizer

Fertilizer type	Average, kg ha^{-1}	Energy equivalent, MJ kg^{-1}	Used energy average, MJ ha^{-1}
Di Ammonium Phosphate	100	12.44	1224
Nitrogen	250	66.14	16535
Notassium sulfate	120	13.7	1644

2.7 Energy of chemical pesticides

To assess the magnitude of pesticide input energy per hectare (that is used as fungicide and insecticide), the value of consumed pesticide per hectare was quantified through the collected questionnaires from the farmers. Additionally with respect to the equivalents for energy resources, the content of per unit pesticide consumption was multiplied by the amount of consumed pesticide. Hence the input energy of pesticide per hectare was evaluated according to the Equation 10 (Kitani, 1999). Energy related to the pesticides is related to its active substance, for instance benomyl (Benlate) as the active substance of fungicide is 50% per kg.

$$E_p = W_p \times EI_p \tag{10}$$

where, E_p: energy of pesticide, MJ ha^{-1}; W_p: the value of active substance of consumed pesticide, kg ha^{-1}; EI_p: pesticide energy in each unit, MJ kg^{-1}.

The input energy of chemical substances and pesticides includes production energy, packaging and transportation. Table 4 shows different type of pesticides and their energy.

Table 4 Average energy of used pesticides

Pesticide type	Average, kg ha^{-1}	Energy equivalent, MJ kg^{-1}	Used energy average, MJ ha^{-1}
Insecticide	5	199	995
Fungicides	5	397	1985

2.8 Transportation energy

In agriculture, transportation occurs within or around a farming land, through trucks, tractors, trailers or other machinery vehicles. Transportation energy is calculated both directly and indirectly. Direct energy is the energy of the consumed fuel for transporting the inputs (e.g. pesticides, fertilizers, seeds etc.). For determining the energy of transportation, the value of consumed energy during transportation has been multiplied by the energy content per unit of fuel. The manpower used for transportation has been taken into consideration as well.

2.9 Energy of labor

The input energy of manpower has been calculated according to the information contained in the questionnaires from the farmers and drivers and number of labors required for tillage (tractor driver), fertilizer spreading, spraying, weeding, harvesting, transportations and so on, moreover the time of each operation has been revealed by the farmers and labors. Then through the resources and tables of Ozkan et al. (2004), Kitani (1999), the equivalent energy of manpower had been multiplied by number of labors per hour, then regarding the 8 hours of work per day, the total input energy of manpower was determined.

$$E_1 = W_1 \times EI_1 \tag{11}$$

where, E_1: manpower, MJ ha^{-1}; W_1: working time, hr ha^{-1}; EI_1: the equivalent energy of manpower, MJ hr^{-1}.

In some operations, technical workers have been employed who were paid more than an ordinary labor, but in calculating the energy of labor, they were considered as the ordinary labor.

2.10 Calculating the produced energy (output energy)

In this study, sugar beet crop was considered to be the produced energy which is actually the output energy of the system. If the weight of dry matter be 26% of the total weight and takes the different combinations of sugar beet into account, then the determined energy will be according to the Table 5. It should be noted that the energy from foliage which was returned to the soil to increase soil organic matter was not considered in the calculation. Table 5 displays the energy combinations of sugar beet (Kochaki, 1994). The total energy content of sugar beet per hectare was calculated according to the sugar beet crop yield per hectare, the percentage of sugar beet dry matter components and the energy content of those components were shown in Table 5. Generally, the equivalent energy for sugar beet is 16.8 MJ kg^{-1}, which was multiplied by crop output (kg ha^{-1}) to calculate total output energy (Singh et al., 1997).

Table 5 The energy combinations of sugar beet

Compounds	Percentage of total, %	Energy, MJ kg^{-1}
Carbohydrate	22.33	16.7
Proteins and other nitrogenous materials	1.73	18.83
Saponins, fat and organic acids	1	37.67
Other organic materials	0.15	24.41
Minerals	0.87	0

2.11 Energy ratio

This index reveals the relationship between the input and output energy of the system which is resulted from dividing the energy of produced crops by the total input energy. This fraction indicates the effects of per unit of input energy on achieving the consumers' goals. Consumer's goal could be food, produced biomass and so on (Ju et al., 2006). For any agricultural system, the ratio of output to input energy is proportional with the performance of the system. The ratio reveals a higher level of energy efficiency in production, as it gets greater than one.

2.12 Net energy output

The net energy output results from subtracting input energy from output energy. Its unit depends on the considered unit for input and output energy and is expressed per hectare (e.g. MJ ha^{-1}) and can be positive or negative. If negative, shows a lack of energy efficiency in the production system.

2.13 Energy productivity

Energy productivity is an index of the amount of product per unit of input energy and is obtained by dividing the amount of crop in kg or tons by the total input energy per unit area. Energy productivity varies depend on type of crop, location and time and can be used as an indicator to evaluate energy efficiency of producing a specific crop in various systems. To enhance the energy productivity in a system, one can reduce input energy, improve crop yields or decrease wastes (Ju et al., 2006). The ratio of energy ratio to energy productivity is the crop's calorific value.

2.14 Energy intensity (specific energy)

Specific energy is the reverse of energy productivity and indicates the input energy per unit of crop production. Energy intensity is equal to the ratio of input energy to crop's weight.

3 Results and discussions

The physical energy consists of labor, animal, farming machinery and tractor, electricity and diesel energy (Ozkan et al., 2004), so in this chapter a table of the statistics obtained from statistical analysis of the questionnaires (105 questionnaires) was presented in order of the agricultural operations (average test of LSD).

3.1 Primary tillage

Primary tillage to prepare the field for cultivation plays an important role in development of crop's root growth, sugar beet in particular; in addition in all areas of study the primary tillage operation was implemented at least once, thus more attention should be paid to primary tillage which consumed high energy. Table 3 reveals the results of the questionnaires analysis.

3.1.1 Energy of tractor

According to Table 6 the tractor average energy for primary tillage of sugar beet cultivation was 438.75 MJ ha^{-1}. Variation range of tractor energy consumption in the probability level of 5% was 48.66 and the standard deviation was 256.82. So, the major and minor tractor energy consumption values were 487.42 MJ ha^{-1} and 390.09 MJ ha^{-1}, respectively (438.75±48.66). Considering the questionnaires and Table 6, it is obvious that for 90 percent of the sugar beet fields, the primary tillage operation was carried out by 75 hp tractors and also the average fuel consumption was equal to 29.05 L ha^{-1}; additionally, more than 95% of tractors and implements had an agricultural efficiency of 81.47% and farming capacity of 0.39 ha hr^{-1}. Moreover the average price for purchasing plows was 474 US dollars.

Table 6 Primary tillage data in sugar beet cultivation

	Tractor power, kW	Fuel consumption, L ha^{-1}	Tractor energy, MJ	Farming capacity, ha hr^{-1}	Efficiency, %	Plow price, $
Average	75.61	29.05	438.75	0.39	81.47	474
Standard deviation	9.87	13.06	256.83	0.24	58.47	409
Range(±)	1.87	2.48	48.66	0.045	11.08	77.6
Major	77.48	31.52	487.42	0.43	92.55	551.8
Minor	73.74	26.57	390.09	0.34	70.39	396.5

3.1.2 Energy of diesel fuel

Since the average fuel consumption is 29.05 L ha^{-1}, multiplying it by the equivalent energy of diesel fuel (47.8 MJ L^{-1}), the average of obtained fuel energy was 1388 MJ ha^{-1}.

3.1.3 The average consumed energy in primary tillage operations

Since there is no energy related to labors or inputs (e.g. pesticides, seeds, fertilizers and so on) in primary tillage operations, the total energy required for primary tillage operations equals to the total energy of tractors and fuel.

Table 7 reveals the above statements, thus the average physical energy for tillage operations was 1827.34 MJ ha^{-1}. This figure was approximately large. With regard to the fact that more than 90% of primary tillage operations in all areas of study, was implemented by 75 hp tractors (medium tractors), and more than 85% of utilized plows are of three blade moldboard type, to reduce energy and fuel consumption and increase field capacity and farming efficiency in tillage operations, plow maintenance and settings related to depth and width of tillage and longitudinal and lateral balance of moldboard plow should be implemented. It should be tried to use new tillage methods such as reduced tillage or no-tillage methods, as well as appropriate plows and tractors.

Table 7 The average consumed energy in primary tillage operations

Type of consumed energy	Average	Energy equivalent	The average of energy, MJ ha^{-1}
Tractor energy for primary tillage	438.75 (MJ ha^{-1})	1	438.75
Fuel energy	29.05 (L ha^{-1})	47.8 (MJ L^{-1})	1388.59
Total consumed energy			1827.34

3.2 The average of the total consumed energy during various cultivating operations of sugar beet

Table 8 reveals the average of consumed energy during different operation of sugar beet cultivation per hectare. According to Table 8, fertilizing after planting accounted the most of energy consumption with 17445.88 MJ ha^{-1} in sugar beet cultivation, which can be reduced by testing soil type and deciding on accurate amount and type of chemical fertilizers or using manure instead. After fertilizing, irrigation was the second energy consumer with 11497 MJ ha^{-1}. Due to the decrement in precipitation and water level of underground aquifers, water and energy consumption in irrigation should be declined using modern methods of irrigation. Manufacturing of the tractors, farming machinery, and irrigation equipment was the third energy consumer with around 6708.90 MJ ha^{-1}, which requires avoiding unjustified operation in producing crops and using crop rotation, reduced tillage or non-tillage methods in cultivating of sugar beet. Spraying stayed at the fourth place of the energy use ranking, which necessitates implementing crop rotation method and biological fighting against pests and diseases of sugar beet and using monogram seeds, which are resistant to fungal diseases and root decomposing, in order to save more energy and protect the environment through a decline in pesticides' chemical pollutants.

Table 8 The average of the total consumed energy during various cultivating operations of sugar beet

Type of the farming operation	Amount of energy consumption, MJ ha^{-1}
Primary tillage	1827.34
Secondary tillage	109.99
leveling	1457.94
Pre-planting fertilizer	2045.53
planting	1710.47
Post-planting fertilizer	17445.88
Irrigation	11497
Spraying	3646.57
Plant protection (weeding and thinning)	1310.16
Harvesting	150.5
Transportation	2077.45
Energy needed for manufacturing machinery and irrigation equipment	6708.9
Total energy consumption	52268.72

3.3 The average energy output in sugar beet cultivation

The average sugar beet yield in Western Azerbaijan province was 43 ton ha^{-1} (Anonymous, 2009). The equivalent of sugar beet energy is 16.8 MJ kg^{-1} (Mahdavi et. al., 2010), so the total energy output was: $43000 \times 16.8 = 722400$ MJ ha^{-1}.

3.4 Direct and indirect energy consumption in sugar beet cultivation

Energy use can be divided into two parts: direct energy (e.g. energy of fuel, the tractor and labor, etc.) and indirect energy (e.g. energy of manufacturing of machinery and irrigation equipment, etc.). The amounts and percentage related to direct and indirect energy are presented in Table 9.

Table 9 The average of the total energy consumption of direct and indirect forms

Type of the energy	Magnitude of energy, MJ	Percentage, %
Direct energy	15458.82	29.58
Indirect energy	36809.2	70.42
Total input energy	52268.02	100

3.5 Energy indicators (indexes)

According to the results, energy indicators of sugar beet production in Western Azerbaijan province (cities of Miandoab and Nagadeh) were calculated. The net energy output, energy productivity and energy ratio were 670131.28 MJ ha^{-1}, 0.82 kg MJ^{-1} and 13.82, respectively. Results revealed that the total input energy during a period of sugar beet cultivation was equal to 52269 MJ, most of which was spent on post-planting fertilizer (33.38%), irrigation operation (22%), manufacturing implement and irrigation equipment (12.84%) and spraying (6.98%), respectively.

This ratio has been announced to be 25.75 in Turkey (Gulistan et al., 2007), 15.4 in Germany (Reinke et al., 2012) and 11 to 29 in Europe (Kitani, 1999). Asgharipour et al. (2012) have obtained the ratio of output to input energy of 13.4 in the province of Khorasan Razavi and Mahdavi et al. (2010) found it was 6.95 in the Agricultural Company of Khezri. In comparison with

Khezri Company, the studied regions were in a better situation but it was in a weak situation compared with indexes of Ozkan et al. (2004). There are two reasons for that: first, sugar beet crop yield is 60 tons per hectare in Turkey while it is 43 in studied region and the second, the irrigation requirement is much less in Turkey due to the large amount of rainfall compared with the region of study.

Asgharipour et al. (2012), Farid et al. (2013) and Mahdavi et al. (2010) also concluded that fertilizers, irrigation and fuel were the greatest energy consumers in sugar beet cultivation in their regions of study. In this research, it was found that the similarity between the results of this study and the above studies is due to the great similarity between sugar beet cultivation farming systems and the utilized tractors and farming machinery in different parts of Iran.

The second energy consumer was irrigation. That was because of the relatively dry climate with low rainfall and also summer cultivation of this crop in Iran. Hence, due to high water requirement of sugar beet, irrigations with slight intervals and high quantity is necessary. On the other hand, the flooding and furrow irrigation methods are common in the region of study and also the inclined lands which decreases the infiltration of water into the soil, lead to high energy consumption of irrigation. Hence modern methods of irrigation are suggested to decline energy consumption. The third high energy consumption was related to tractors and fuel, which was because of using relatively old tractors and implements in the fields.

The difference of research region in comparison to other investigated areas can be related to geographical location and climate condition of the research area which is located in a relative dry situation. Also, conventional field of Western Azerbaijan were divided into relatively small lands which aren’t leveled and they are irrigated with flood irrigation method. Unevenness of field and fool method of irrigation waste a lot of water. Hence, leveling of fields using laser leveler and new methods of irrigation such as wheel move will decrease required the water and finally required energy. Some operations such as weeding, cutting sugar beet head were conducted by labors which require a lot of energy. Mechanisation and conducting those using modern machines will diminish their costs.

Also conventional tillage was conducted in Iran in which all harvesting residue was removed from the field by firing or other mechanical methods. This caused the field will be free of organic material and require a lot of chemical fertilizers and farmyard manure which increases required energy for sugar beet production.

4 Conclusion

This research investigates energy requirement of sugar beet production in Western Azerbaijan Province of Iran. The required energy was calculated for all farming operation of this crop and finally total input and output energy were computed. The main conclusions of the research are as follow:

The largest energy consumer in sugar beet cultivation was post-planting fertilizing with around 17445.88 MJ ha^{-1}, which can be reduced by using soil testing methods to evaluate the accurate amount and type of fertilizer or using manure instead. After post-planting fertilizer, irrigation was the second energy consumer with 11497 MJ ha^{-1}. Using modern methods of irrigation, energy consumption declines as a result of less water consumption. Manufacturing tractors, farming machinery, and irrigation equipment was the third energy consumer with 6708.90 MJ ha^{-1}, which requires avoiding unjustified operation in producing crops and using crop rotation, reduced tillage or non-tillage methods in cultivating sugar beet, so that the consumed energy in this sector could be reduced. Spraying stayed at the fourth place of the energy consumer’s ranking, which necessitates implementing crop rotation methods and biological fighting against pests and diseases of sugar beet and using monogram seed, which is resistant to fungal diseases and root decomposing to save energy.

According to the results, energy indicators of sugar beet production in Western Azerbaijan province (the cities of Miandoab and Nagadeh) were net energy output, energy productivity and energy ratio of 670131.28 MJ ha^{-1}, 0.82 kg MJ^{-1} and 13.82, respectively. In comparison with other parts of Iran, the studied regions were in a better situation but are in a weak position compared with Turkey. There are two reasons for that: first, sugar beet crop yield is 60 tons per hectare in Turkey while it is

43 tons per hectare in the study region and the second, the irrigation requirement is much less in Turkey due to the large amount of rainfall compared with the region of study.

It was concluded to decrease required energy of sugar beet production small fields should be merged to develop field size. Such developed field must be leveled and new methods of irrigation applied to decrease the required water. The field should be mechanized and with application new method of tillage such as reduced tillage and no tillage, the required energy for primary and secondary tillage can be reduced or eliminated.

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