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Determination of Energy Balance for Sugar Beet Production

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ABSTRACT: This conducted to evaluate the energy balance in sugar beet production in Khoy a northwestern city of Iran. For this reason data was collected by using questionnaires and face to face interviews with 110 farmers. Results showed that total energy inputs and output were 60575.604 and 225075 MJ ha-1, respectively. Efficiency Energy Ratio (ER) was 3.72 and Energy Productivity (EP) was 0.96 MJha-1.The results also showed that the indirect and non-renewable energy sources were 72.17% and 88.57%, respectively. The high rate of non-renewable and indirect energy inputs proved an intensive use of pesticides, chemical fertilizers, tractor and machinery and irrigation system consumption in these agro-ecosystems. Finally, giving a proper information to farmers about extension services in case of machinery combination, fertilizing, spraying and soil test, in a proper time, can have a great effect in sustainability of the sugar beet production.

Keywords: Energy, Sugar beet, ER, EP, Indirect Energy, Non-renewable Energy

INTRODUCTION

The effective usage of agricultural products and increasing the amount of production in a unit area are both necessary because the extreme boundaries of agricultural areas in Iran have been reached. Therefore the most suitable method for products such as sugar beet plants must be determined and applied. Sugar, which is obtained from the sugar beet plant, has an important place in the human diet. Moreover the head and the leaves, which are byproducts of sugar beets, are used for producing meals (residues of sugar beet), which are an important nutrient source in animal diet.

Since the energy scenario of crop production has changed with the introduction of modern inputs, efficient energy use in agricultural production is an important consideration for sustainability in agriculture.Energy flows are an important component of agricultural ecosystems and many serious environmental problems are related to increased conventional energy utilization due to the adoption of modern technology.

Sugar beet is mainly used for human food, livestock, and as a raw material for industry. Sugar content of sugar beet is about 25% higher than found in sugar cane (Erdal *et al.* 2007). Energy balances are used for the environmental assessment of agriculture, because they indicate intensity and environmental effects of production (Hülsbergen *et al.* 2001; Castoldi and Bechini 2010). High energy output and energy gain are worthwhile, because arable land is limited and the demand for food, feed and renewable raw materials increases (FAO 2009). Thus, the improvement of energy gain and energy efficiency through optimizing energy input and increasing energy output contributes significantly to sustainable development in agriculture. There is a close relationship between agriculture and energy. Agriculture uses energy, when supplies it in the form of bioenergy. At the present time, the productivity and profitability of agriculture depend upon energy consumption (Tabatabaeefar *et al.* 2009).

A three year study conducted to investigate energy use pattern in Abyek a town in Ghazvin Province of Iran. Revealed an increasing trend for energy ratio and energy productivity from 2008 to 2010 (Naderloo *et al.* 2013)

Sugar beet is the widely grown crop in Iran with 3467373 tons in a cultivation area of 82516 ha with 42.02 (tonha^{-1}) yield (Iranian Sugar Factories Syndicate 2013).

Sugar beet cultivation in Khoy city is 900 hectares. With yield of 52 tonha^{-1} with more than 40000 tons sugar beet production delivered to the sugar factories (Anonymous 2015).

This study aimed to evaluate the energy balance in sugar beet production in Khoy a city in the northwestern of Iran.

MATERIALS AND METHODS

Khoy city has an area of 2544 square kilometers.Its average altitude is 1130 meters above sea level. Geographically located 38 degrees 32 minutes north latitude and 58 degrees 44 minutes east of the Greenwich meridian (Geographical location Khoy city 2015). Sample farms were randomly selected from the villages in the study area by using a stratified random sampling technique. The sample size was calculated using the Neyman method as is shown below Eq. (1) (Yamane 1967):

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

In the above formula n is the required sample size; *N* is the number of holdings in 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 of h stratification; *d* is the precision where $(\bar{x} - \bar{X})$; *z* is the reliability coefficient (1.96 which represents the 95% reliability); $D^2 = d^2/z^2$.

For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used.

Thus, the number of 110 was considered as sampling size. This study was conducted in October 2014 in Khoy, a city in the northwestern of Iran. For this investigation data was collected from 125. The data used in the study was obtained by using face-to-face interview method. Inputs used in the production of sugar beet were specified in order to calculate the energy equivalences in the study. Inputs in sugar beet production were: human labour, machinery, diesel fuel, chemical fertilizers, farmyard manure, pesticides, fungicides, herbicides as biocides, water for irrigation, and electricity. The output was considered sugar beet yield.

The volumetric fuel consumption for a diesel engine can be calculated as (Eq. 2):

$$Q = (2.64X + 3.91 - 0.203\sqrt{738X + 173}) \times X \times P_{pto} \quad (2)$$

In the above formula:

Q = diesel fuel consumption at partial load, L/h (gal/h)

X = the ratio of equivalent PTO power (PT) to rated PTO power (P_{pto}), decimal

P_{pto} = the rated PTO power, kW (hp) (Grisso *et al.* 2004).

The production energy of tractors and agricultural machines was calculated by using the following equation (Eq. 3).

$$Mpe = \frac{GMp}{TW} \quad (3)$$

In the above formula, M_{pe} is the energy of the machine per unit area, $MJha^{-1}$; *G* is the mass of machine, kg; M_p is the production energy of machine, $MJkg^{-1}$; *T* is the economic life, *h*; and *W* is the effective field capacity, hah^{-1}(Gezer 2003; Canakci*et al.* 2005).

Energy production of tractors and agricultural machinery per unit time was calculated using the following formula (Eq. 4):

$$Mpt = \frac{GMp}{T} \quad (4)$$

Where M_{pt} is the energy of the machine per unit time, $MJhr^{-1}$ (Table 1)

Table 1: Energy equivalent to the production of tractors and agricultural machinery.

Agricultural processes	Energy production (MJ/h)
Tractor	28.5
Moldboard plow	45
Disc harrow	59
Leveler	37.25
Row planter	94.2
Fertilizer	59.1
Mounted sprayer	43
Cultivator	23.8
Topper	67.1
Lifter	18

The energy equivalents given in Table 2, were used to calculate the input amounts. The input and output were calculated per hectare and then, these input and output data were multiplied by the coefficient of energy equivalent. Following the calculation of energy input and output values, the energy ratio (energy use efficiency), energy productivity and net energy were determined (Borin*et al.* 1997; Mandal *et al.* 2002; Zentner*et al.* 2004; Mohammadi*et al.* 2008) (Eq. 5, 6, 7 and 8):

$$\text{Efficiency Energy Ratio(ER)} = \frac{\text{Energy output (MJ } ha^{-1})}{\text{Energy input (MJ } ha^{-1})} \quad (5)$$

$$\text{Energy productivity(EP)} = \frac{\text{sugar beet output (kg } ha^{-1})}{\text{Energy input (MJ } ha^{-1})} \quad (6)$$

$$\text{Net Energy Gain}(NEG) = \text{Energy output (MJ } ha^{-1}) - \text{Energy input (MJ } ha^{-1}) \quad (7)$$

Table 2: Energy equivalences of inputs and outputs.

Energy source	Units	Energy equivalences MJ	References
Human labor	h	2.2	(Pimentel and Pimentel 1979)
Diesel fuel	Lit	47.8	(Kitani 1999)
N	Kg	74.2	(Lockeretz 1980)
P2O5	Kg	13.7	(Lockeretz 1980)
K2O	Kg	8.8	(Lockeretz 1980)
Farmyard manure	Kg	0.3	(Singh J. M. 2002)
Pesticide	Kg	363	(Fluck and Baird 1982)
Fungicide	Kg	99	(Fluck and Baird 1982)
Herbicide	Kg	288	(Kitani 1999)
Water and Irrigation	M^3	0.63	(Yaldiz *et al.* 1993)
Electricity	KWh	12	(Demircan *et al.* 2006)
Seed	kg	54	(Kitani 1999)
Sugar beet	kg	3.89	(Austin *et al.* 1978)

All data on energy inputs and outputs, sugar beet yields was calculated and entered into Excel 2013's spread sheet and SPSS 21 software programs and analyzed.

RESULTS AND DISCUSSION

Energy input of the different operations from tractor and agricultural equipments for tillage, planting, cultivation and harvesting in sugar beet production systems, their balance of energy equivalents, and percentages in the total energy input showed in the Table 3.Energy input for different machine operations was 3693.18 MJ and 6.1% of the total energy production of sugar beet.

In Khoy, different operations including irrigation, weeding, breaking crust, topping, cumulating and machine operations of sugar beet is mainly done manually. Human energy inputs for manual operation is 1095.75 MJ which is equal to 1.81 percent of total energy consumption of sugar beet production (Table 4).

Table 3: Energy inputs operations tractors and agricultural equipment in sugar beet production.

Energy source	Energy equivalences (MJ)	Operations (h)	Energy machinery (MJ/ha)
Tractor	27.28	47.41	1293.34
Moldboard plow	45	3.42	153.90
Disc harrow	59.6	3.09	184.16
Leveler	37.25	2.02	75.25
tillage Energy			413.31
Row planter	94.21	2.3	216.68
Fertilizer	59.13	3.5	206.94
Mounted sprayer	43.00	3.33	143.19
cultivator	23.84	2.74	65.32
plant and cultivation Energy			632.13
Topper	67.05	2.89	193.77
lifter	18.00	3.25	58.50
trailer	64.40	11.96	770.22
loader	37.25	8.91	331.90
harvester Energy			1354.40
total			3693.18

Table 4: Energy inputs operations manual in sugar beet production.

Energy Human labor	Energy equivalences (MJ/h)	Operations (h)	Energy (MJ/ha)	Percentage of total energy (%)
Weeding and Breaking Crust	2.2	126.95	279.29	25.49
Cumulating	2.2	88.9	195.58	17.85
Topping	2.2	152.63	335.786	30.64
Driver	2.2	47.41	104.302	9.52
Irrigation	2.2	82.18	180.796	16.50
Total		498.07	1095.75	100

In a study of labor input energy of 1932 MJ equals to 3.9 percent of total energy input (Yousefi *et al.* 2014), in another study 385.67 MJ obtained (Haciseferogullari *et al.* 2003).Energy input of chemical fertilizer and manure, chemical pesticides, irrigation and seed also output of energy from sugar beet production is Showed in Table 5. The results showed that the energy consumed for chemical fertilizers was 24155.12MJ, among themthe most amount related to N-fertilizer with19573.22 MJ. In a study conducted in the Kermanshah Province of Iran, on the production of sugar beet, nitrogen fertilizer with 27.9% has the largest amount of the energy input (Yousefi *et al.* 2014).

Table 5: Energy of fertilizers, pesticides, Irrigation and sugar beet yield in sugar beet production.

Energy source	Unit	Energy Equivalences (MJ)	Operations (Kg/ha)	Energy (MJ/ha)
fertilizer				
N	Kg	74.2	263.79	19573.2
P_2O_5	Kg	13.7	193.13	2645.9
K_2O	Kg	9.7	199.59	1936
Farmyard manure	Kg	0.3	19070	5721
Biocides				
Pesticide	Kg	363	2.98	1081.74
Fungicide	Kg	99	1.47	145.5
Herbicide	Kg	288	3.25	936
Diesel fuel	lit	47.8	211.8	10124
Electricity	KWh	12	470.02	5640.2
Irrigation systems	m3	0.63	12500	7875
Seed	kg	54	2	108
Sugar beet	kg	3.89	57860	225075.4

In another study on an open field strawberry production systems energy related to nitrogen with 41% was the maximum and the greatest share of energy related to greenhouse strawberries production systems is natural gas and electricity, 58.4% and 27.42% respectively (Khoshnevisan *et al.* 2014).The input and output energy used in sugar beet production systems, their energy equivalents and percentages in the total energy input presented in Table 6. The results revealed that total energy input was 60575.6 $MJha^{-1}$. Chemical fertilizer used in sugar beet production systems had a high share with 39.88% (Table 6 and Fig. 1). Diesel fuel energy used in sugar beet production systems with 16.71% has the second place in the total energy input. The lowest share of the total energy input was belonged to seed with 0.18%. In this study sugar beet yield was 57860 $kgha^{-1}$ and the total energy equivalents was 225075 $MJha^{-1}$.In many other studies the energy input ranged between 13 and 30 $GJha^{-1}$ (Kuesters and Lammel 1999; Hülsbergen *et al.* 2001; Tzilivakis *et al.* 2005).

Table 6: Energy inputs, outputs and the ratio in sugar beet production.

Energy source	Energy (MJ/ha)	Percentage of total energy (%)
Inputs		
Tractor and machinery	3693.18	6.10
Human labor	1095.754	1.81
Chemical fertilizer	24155.1	39.88
Farmyard manure	5721	9.44
Biocides	2163.27	3.57
Diesel fuel	10124.04	16.71
Electricity	5640.24	9.31
Irrigation	7875	13
Seed	108	0.18
Total Inputs	60575.604	100
Output		
Sugar beet	225075	

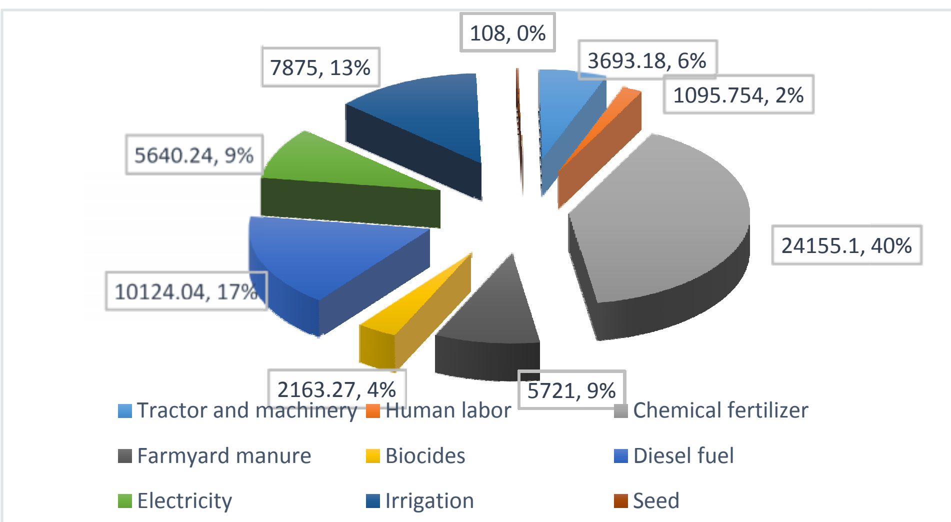

Fig. 1. Energy inputs, outputs and the ratio in sugar beet production ($Mjha^{-1}$).

Total energy input, direct and indirect energy, renewable and Non-renewable forms for sugar beet farms are given in Table 7. Direct and indirect energy inputs were recorded as 27.83 and 72.17%, respectively. Renewable and non-renewable energy Sourceswere calculated as 11.43 and 88.57%, respectively.Results revealed that indirect energy consumption was higher than direct energy in sugar beet farms; the same was observed for non-renewable versus renewable energy sources.

Table 7: Energy indices and different form of energy in potato production.

Indicators	Unit	Quantity	Percentage of total energy (%)
Direct energy [a]	MJ/ha	16860.034	27.83
Indirect energy [b]	MJ/ha	43715.57	72.17
Renewable energy [c]	MJ/ha	6924.754	11.43
Non-renewable energy [d]	MJ/ha	53650.85	88.57
Total energy input	MJ/ha	60575.60	100
Output energy	MJ/ha	225075	
Sugar beet yield	Kg/ha	57860	
Energy Ratio (ER)	%	3.72	
Energy Productivity (EP)	MJ/ha	0.96	
Net Energy Gain (NEG)	MJ/ha	164499.80	

a: Includes human labor, diesel fuel, electricity. b: Includes seeds, chemical fertilizers, manure, pesticides, tractor and machinery, irrigation system. c: Includes human labor, seeds, manure. d: Includes diesel fuel, pesticides, chemical fertilizers, tractor and machinery, electricity, irrigation system.

The high rate of non-renewable and indirect energy inputs indicate an intensive use of pesticides, chemical fertilizers, tractor and machinery and irrigation system consumption in these agro-ecosystems. Results of energy indicators for sugar beet production systems are shown in Table 7. Accordingly, the energy ratio (ER) obtained is 3.72. High energy ratio in sugar beet production systems is due to higher energy output in comparison to energy consumed. Energy use efficiency was reported 22.12 for sugar beet production systems in Kermanshah Province in Iran (Yousefi *et al.* 2014) and 25.75 for sugar beet production systems in Turkey (Erdal *et al.* 2007).

CONCLUSION

The results showed that the maximum energy consumption of chemical fertilizers 24155.1 MJha-1 and 39.88% of the total energy input. Indirect and non-renewable energy sources were as 72.17 % and 88.57%, respectively. The high rate of non-renewable and indirect energy inputs indicate an intensive use of pesticides, chemical fertilizers, tractor and machinery and irrigation system consumption in these agroecosystems. The efficiency energy ratio (ER) obtained is 3.72. High energy ratio in sugar beet production systems is due to higher energy output in comparison to energy consumed.

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