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Determination of energy balance for sugar beet production (Case study of Iran)

***Mohammad Ali Salehi**

**Department of Agricultural, Mahabad branch, Islamic Azad University, Mahabad, Iran*

ABSTRACT

This conducted to evaluate the energy balance in sugar beet production in Bukan a northwestern city of Iran. For this reason, data was collected by using questionnaires and face to face interviews with 327 farmers. Results showed that total energy inputs and output were 59560.06 and 252850 MJ ha-1, respectively. Efficiency Energy Ratio (ER) was 4.25 and Energy Productivity (EP) was 1.09 MJha-1. The results also showed that the indirect and non-renewable energy sources were 63.10% and 94.83, 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.

Key words: Energy, ER, EP, Sugar beet.

1- 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 [1]. Energy balances are used for the environmental assessment of agriculture, because they indicate intensity and environmental effects of production[2], [3]. High energy output and energy gain are worthwhile, because arable land is limited and the demand for food, feed and renewable raw materials increases [4]. 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 [5].

Sugar beet is the widely grown crop in Iran with 6104000 tons in a cultivation area of 109000 ha with 56 (tonha^{-1}) yield [6].

Sugar beet cultivation in bukan city is 1500 hectares. With yield of 65 tonha^{-1}with more than 90000tons sugar beet production delivered to the sugar factories[7].

This study aimed to evaluate the energy balance in sugar beet production in Bukan a city in the northwestern of Iran [8].

Materials and methods

Bukan city has an area of 2541.30 square kilometers. Its average altitude is 1365 meters above sea level. Bukan city is situated in West Azerbaijan province at

northwest of Iran (36° 32’ N, 46° 13’ E) [9]

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) [10]:

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

In the above formula n is the required sample size; N is the number of holdings in target population; Nh is the number of the population in the h stratification; Sh is the standard deviation in the h stratification, Sh2 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); D2 =d2/z2.

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

Thus, the number of 327 was considered as sampling size. This study was conducted in October 2021 in Bukan, a city in the northwestern of Iran. For this investigation data was collected from 327. 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 energy equivalents given in Table 1, 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 [11]–[14] (Eq. 2, 3 and 4):

$$\text{Efficiency Energy Ratio(ER)} = \frac{\text{Energy output } (\text{MJ } ha^{-1})}{\text{Energy input } (\text{MJ } ha^{-1})} \quad (2)$$

$$\text{Energy productivity(EP)} = \frac{\text{sugar beet output } (\text{kg } ha^{-1})}{\text{Energy input } (\text{MJ } ha^{-1})} \quad (3)$$

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

All data on energy inputs and outputs, sugar beet yields was calculated and entered into Excel 2016's spread sheet and SPSS 22 software programs and analyzed.

Table 1: Energy equivalences of inputs and outputs

Energy source	Units	Energy equivalences MJ	References
tractor and machinery	h	62.7	[15]
Human labor	h	2.2	[16]
Diesel fuel	Lit	47.8	[17]
N	Kg	74.2	[18]
P2O5	Kg	13.7	[18]
K2O	Kg	8.8	[18]
Farmyard manure	Kg	0.3	[19]
Pesticide	Kg	363	[20]
Fungicide	Kg	99	[20]
Herbicide	Kg	288	[17]
Water and Irrigation	M^3	0.63	[21]
Electricity	KWh	12	[22]
Seed	kg	54	[17]
Sugar beet	kg	3.89	[23]

2- Results and Discussion

Energy input of the different operations from tractor and agricultural equipment's 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 2.

Energy input for different machine operations was 2330.56 MJ and 3.91% of the total energy production of sugar beet.

In Bukan, 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 1419.0 MJ which is equal to 2.38 percent of total energy consumption of sugar beet production (Table 2).

In a study of labor input energy of 1932 MJ equals to 3.9 percent of total energy input [24], in another study 385.67 MJ obtained [25].

Energy input of chemical fertilizer and manure, chemical pesticides, irrigation and seed also output of energy from sugar beet production is showed in Table 2. The results showed that the energy consumed for chemical fertilizers was 29462.1MJ, among them the most amount related to N-fertilizer with 25000.2 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 [24]. 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 [26].

The input and output energy used in sugar beet production systems, their energy equivalents and percentages in the total energy input presented in Table 3. The results revealed that total energy input was 59560.06 $MJha^{-1}$. Chemical fertilizer used in sugar beet production systems had a high share with 49.47% (table3 and figure 1). Diesel fuel energy used in sugar beet production systems with 18.73% 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 65000 $kgha^{-1}$ and the total energy equivalents was 252850 $MJha^{-1}$.In many other studies the energy input ranged between 13 and 30 $GJha^{-1}$[2], [27], [28].

Table 2: Energy of fertilizers, pesticides, Irrigation and sugar beet yield in sugar beet production.

Energy source	unite	Energy Equivalences (MJ)	Operations (unite/ha)	Energy (MJ/ha)
tractor and machinery	Hr	62.7	37.17	2330.6
Human labor	Hr	2.2	644.98	1419.0
fertilizer				
N	Kg	74.2	336.93	25000.2
P2O5	Kg	13.7	190.1	2604.4
K2O	Kg	9.7	184	1784.8
Farmyard manure	Kg	0.3	5186	1555.8
Ca and Mg	Kg	8.8	8.26	72.7
Total fertilizer				31017.9
Biocides				
Pesticide	Kg	363	3.94	1430.2
Fungicide	Kg	99	1.65	163.4
Herbicide	Kg	288	3.06	881.3
Total Biocides				2474.9
Diesel fuel	lit	47.8	233.33	11153.17
Electricity	KWh	12	758.53	9102.36
Irrigation systems	M3	0.63	3107.2	1957.54
Seed	kg	54	1.94	104.76
Sugar beet	kg	3.89	65000	252850

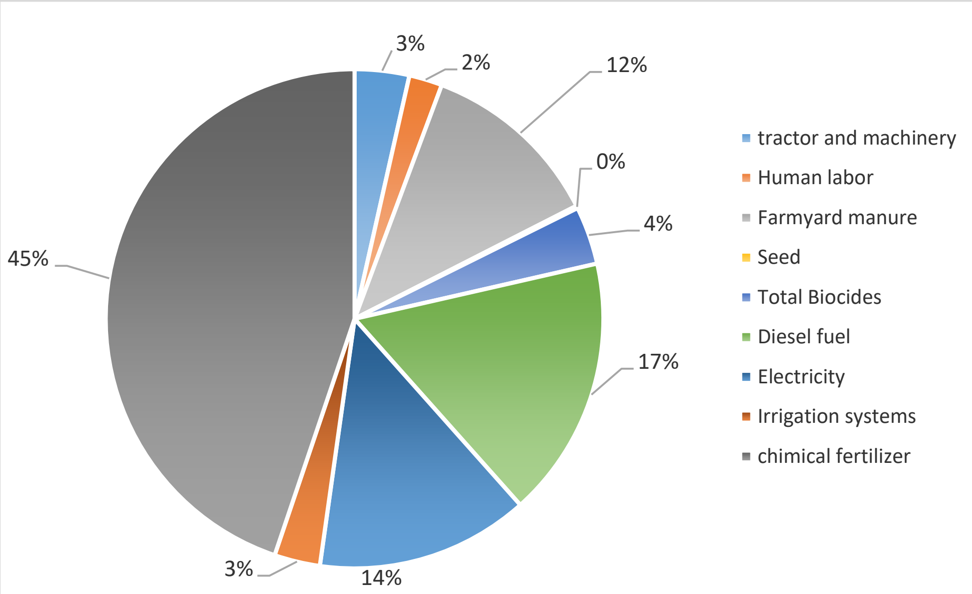

Figure1: Energy inputs, outputs and the ratio in sugar beet production (Mjha^{-1}).

Table3: Energy inputs, outputs and the ratio in sugar beet production

Energy source	Energy (MJ/ha)	Percentage of total energy (%)
Inputs		
Tractor and machinery	2330.56	3.91
Human labor	1419.0	2.38
Chemical fertilizer	29462.1	49.47
Farmyard manure	1555.8	2.61
Biocides	2474.9	4.16
Diesel fuel	11153.174	18.73
Electricity	9102.4	18.73
Irrigation system	1957.5	3.29
Seed	104.76	0.18
Total Inputs	59560.60	100
Output		
Sugar beet	252850	

Total energy input, direct and indirect energy, renewable and Non-renewable forms for sugar beet farms are given in Table 4. Direct and indirect energy inputs were recorded as 36.39 and 63.61%, respectively. Renewable and non-renewable energy sources were calculated as 5.17 and 94.83%, 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. 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.

Table 4 :Energy indices and different form of energy in potato production.

Indicators	Unit	Quantity	Percentage of total energy (%)
Direct energy [a]	MJ/ha	21674.5	36.39
Indirect energy [b]	MJ/ha	37885.57	63.61
Renewable energy [c]	MJ/ha	3079.5	5.17
Non-renewable energy [d]	MJ/ha	56480.54	94.83
Total energy input	MJ/ha	59560.06	100
Output energy	MJ/ha	252850	
Sugar beet yield	Kg/ha	65000	
Energy Ratio (ER)	%	4.25	
Energy Productivity (EP)	MJ/ha	1.09	
Net Energy Gain (NEG)	MJ/ha	193289.94	

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

Results of energy indicators for sugar beet production systems are shown in Table 4. Accordingly, the energy ratio (ER), Energy Productivity (EP) and Net Energy Gain (NEG) obtained 4.25%, 1.09 MJha-1 and 193289.94 MJha-1 respectively. 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 [24] and 25.75 for sugar beet production systems in Turkey [1].

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