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ENERGY USE AND GREENHOUSE GAS EMISSION ANALYSIS FOR SUGAR BEET PRODUCTION UNDER THREE CULTIVATED AREA LEVELS

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ABSTRACT
This study was conducted to determine the energy use pattern, greenhouse gas (GHG) emission and energy input relationship with yield and total GHG emission for sugar beet production under three cultivated area levels in East Azerbaijan province, Iran. For this purpose the data were collected from 37 sugar beet farms. The following results were obtained from this study: the total energy required and GHG emission of sugar beet production was calculated about 64920 MJ ha^{-1} and 2177 MJ ha^{-1}, respectively. The energy indices such as energy use efficiency, energy productivity and net energy were computed as 17.20, 1.02 kg MJ^{-1} and 1051822.07 MJ ha^{-1}, respectively. The highest share of energy consumption and GHG emission belonged to electricity. The large farms had the lowest energy use and total GHG emission among farms groups. With respect to regression models results, the impact of human labor, nitrogen, diesel fuel and phosphate in energy model and impact of machinery, diesel fuel, nitrogen, farmyard manure, biocides and electricity in GHG emission model was significantly. Also, the R^2 was calculated as 0.99 for both of models. Moreover, the highest MPP value of yield and GHG emission model was belonged to biocides and seed, respectively.

KEY WORDS: Emission, Energy, Regression modeling, Sensitivity analysis, Sugar beet.

INTRODUCTION

Sugar beet is mainly used for human food, livestock feed and in industry. The two main sources of sucrose (sugar) for human consumption are sugar cane and sugar beet. About one fourth of the world's sugar production comes from sugar beet (about 40 million tons in 1999). Sugar content of sugar beet is about 25% higher than that found in sugar cane (Erdal et al. 2007). In Iran, sugar beet is one of the most important farm products due to its role in the nutrition and health of people. It should be noted, Iran has the fourteenth place of sugar beet production in the world (FAO, 2012). In Iran, East Azerbaijan province is one of the main producers of sugar beet with yield of 20230 ton (Anon, 2012). In agricultural section, energy is an input which is used for various reasons such as increasing productivity, enhancing food security and contributing to rural economic development. Energy use in agriculture has been increased in response to increasing population, limited supply of arable lands, and a desire for higher standards of living. Tendency towards intensive use of energy in agricultural systems is profoundly due to mechanization, using chemical fertilizers, high-yielding

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seeds and synthetic pesticides (Ghorbani et al. 2010). Greenhouse gases (GHG) absorb infrared radiation in the atmosphere, trapping heat and warming the earth's surface, this is known as the greenhouse effect. Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation since the early 20th century. GHG is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. GHG emission greatly affects the temperature of the Earth (Le Treut et al. 2007). So, dependence of conventional agricultural systems on intensive using of energy is one of the main reasons for creation of environmental problems such as global warming in the most developing and developed countries. Resource and energy use efficiency is one of the principal requirements of eco-efficient and sustainable agriculture (Ghorbani et al. 2010). Accordingly, establishing functional relationship between inputs and outputs is very useful in terms of determining the elasticity and sensitivity of inputs on the yield of agricultural crops. The objective of sensitivity analysis of model parameters is to ascertain how a given model depends on its input factors. It also helps us understand the behavior of the model, and shows how different parts affect the model output (Pishgar-Komleh et al. 2013). Many researchers surveyed the energy consumption and GHG emission in recent decade. Kuesters and Lammel (1999) examined the energy efficiency of sugar beet production in Europe. Tzilivakis et al. (2005) reported the total energy use of sugar beet production was between 15.72 and 25.94 GJ ha-1; also, their results revealed the total GHG emission in producing was about 0.024 $kgCO_{2eq.}$ per ton. Erdal et al. (2007) investigated the energy use pattern of sugar beet production in Turkey. Reineke et al. (2013) balanced energy consumption for sugar beet cultivation in commercial farms in Germany. Yousefi et al. (2014) considered the energy requirement and GHG emission of sugar beet production in Kermanshah province of Iran. For other crops, Soni et al. (2013) surveyed the energy consumption and GHG emission in rainfed agricultural production systems of Northeast Thailand. Khoshnevisan et al. (2013) surveyed the energy consumption and GHG emission of wheat production. In another study, Nabavi-Pelesaraei et al. (2013a) modeled the energy consumption and GHG emission for eggplant production. Pishgar-Komleh et al. (2013) studied an analysis of energy use and GHG emission for greenhouse cucumber production in Yazd province, Iran. Soheili-Fard et al. (2014) examined Cobb-Douglas function production for total CO_2 emission modeling of tea production under three cultivated area levels based on CO_2 emitter inputs. Therefore, this study subjective to find an energy use and GHG emission pattern and calculation of functional relationship with them and sugar beet production in East Azerbaijan based on three different farm sizes.

MATERIALS AND METHODS

Case study region and data collection

Data on sugar beet production was collected from the farmers by using a face to face questionnaire performed in February 2013 in East Azerbaijan province, Iran. This province is located in the west north of Iran, within 36° 45′and 39° 26′ north latitude and 45° 05′ and 48° 22′ east longitude (Anon, 2012). The collected information belonged to the 2012-2013 production period. Farms were randomly chosen from the villages in the area of study. The size of sample of each stratification was determined using Eq. (1), derived from simple random sampling method (Kizilaslan, 2009).

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

Where *n* is the required sample size; *s*, is the standard deviation; *t*, is the value at 95% confidence limit (1.96); *N*, is the number of holding in target population and *d*, is the acceptable error (permissible error 5%). For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used. Thus, the number of 37 was considered as sampling size.

Energy balance analysis method

Firstly, the amount of inputs used in the production of sugar beet (biocides, human labor, machinery, seed, farmyard manure, chemical fertilizers, diesel fuel, electricity and water for irrigation) were specified in order to calculate the energy equivalences in the study. The units in Table1 were used to find the input amounts. The amounts of input were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. The previous studies (cited in Table1) were used to determine the energy equivalents' coefficients. The energy equivalences of unit inputs are given in Mega Joule (MJ) unit. The total input equivalent can be calculated by adding up the energy equivalences of all inputs in MJ.

Table 1. Energy equivalent of inputs and output in agricultural production.

Items (unit)	Unit	Energy equivalent (MJ unit^{-1})	Reference
A. Inputs			
1. Human labor	h	1.96	(Mohammadshirazi et al. 201
2. Machinery	kg yr[a]		
(a) Tractor and self-propelled		9-10	(Hatirli et al. 2005)
(b) Implement and machinery		6-8	(Hatirli et al. 2005)
3. Diesel fuel	L	56.31	(Mobtaker et al. 2010)
4. Chemical fertilizers	kg		
(a) Nitrogen		66.14	(Mousavi-Avval, 2011)
(b) Phosphate (P_2O_5)		12.44	(Rafiee et al. 2010)
5. Farmyard manure		11.15	(Unakitan et al. 2010)
6. Biocides	kg	120	(Nabavi-Pelesaraei et al. 2013b)
7. Electricity	kWh	11.93	(Khoshnevisan et al. 2013)
8. Water for irrigation	m^3	1.02	(Khoshnevisan et al. 2013)
9. Seed	kg	50	(Erdal et al. 2007)
B. Output			
Sugar beet	kg	16.8	(Erdal et al. 2007)

[a] The economic life of machine (year).

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Following the calculation of energy input and output equivalents, to assess the energy efficiency of sugar beet production the indices of energy consumption including energy use efficiency, energy productivity, specific energy (energy intensity) and net energy were calculated as follow (Mousavi-Avval et al. 2011).

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ ha}^{-1}\text{)}}{\text{Energy input (MJ ha}^{-1}\text{)}} \quad (2)$$

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

$$\text{Specific energy} = \frac{\text{Energy output (MJ ha}^{-1}\text{)}}{\text{Sugar beet output (kg ha}^{-1}\text{)}} \quad (4)$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}\text{)} - \text{Energy input (MJ ha}^{-1}\text{)} \quad (5)$$

GHG emission

The GHG emission coefficients of agricultural inputs that are shown in Table 2 were applied to calculate the amounts of GHG emission from sugar beet production inputs per hectare. For each input, the amounts of produced GHG were calculated by multiplying the inputs application rate of diesel fuel, chemical fertilizers, biocides, machinery and electricity by their corresponding coefficients that are given in Table 2. For water for irrigation input, the energy usage was converted to the diesel fuel amount and also the total CO_2 emission in water for irrigation input was calculated by multiplying the diesel fuel consumption by GHG coefficient.

Table 2. GHG emission coefficients of agricultural inputs.

Input	Unit	GHG Coefficient (kg CO_{2eq} unit^{-1})	Reference
1. Machinery	MJ	0.071	(Dyer and Desjardins, 2006)
2. Diesel fuel	L	2.76	(Dyer and Desjardins, 2003)
3. Chemical fertilizers	kg		
(a) Nitrogen		1.3	(Khoshnevisan et al. 2013)
(b) Phosphate (P_2O_5)		0.2	(Nabavi-Pelesaraei et al. 2014a)
4. Biocides	kg	6.3	(Lal, 2004)
5. Electricity	kWh	0.608	(Nabavi-Pelesaraei et al. 2014b)

All energy consumption and GHG emission of sugar beet production were calculated and analyzed in various farm size groups, which were classified into three categories as small (<2 ha), medium (between 2 and 4 ha) and large farms (>4 ha) due to the frequency of farm sizes in the sample population. In order to find out whether the calculated values for three groups of farm sizes are different significantly, the ANOVA test was utilized and to compare means, Duncan compare mean test was applied.

Cobb–Douglas function

Cobb–Douglas functions are frequently used in economics to show the relationship between input factors and the level of production. The Cobb-Douglas production function is expressed as follow (Royan et al. 2012). Accordingly, the relation between energy inputs and sugar beet yield and relation between energy inputs and total GHG emission was determined by Cobb–Douglas functions in this research.

Cobb–Douglas function is expressed as follows:

$$Y = f(x)\exp(u) \tag{6}$$

Eq. (6) can be linearized and be further re-written as::

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \qquad i = 1,2, \ldots, n \tag{7}$$

Also, Eq. (7) can be expressed in the following form:

$$\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + \alpha_8 \ln X_8 + \alpha_9 \ln X_9 + \alpha_{10} \ln X_{10} + e_i \tag{8}$$

$$\ln G_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + \alpha_8 \ln X_8 + \alpha_9 \ln X_9 + \alpha_{10} \ln X_{10} + e_i \tag{9}$$

Where Xi stands for corresponding energies as X_1, human labor; X_2, machinery; X_3, diesel fuel; X_4, nitrogen; X_5, phosphate; X_6, farmyard manure; X_7, biocides; X_8, electricity; X_9, water for irrigation; X_{10}, seed; Y_i, sugar beet yield and G_i, total GHG emission.

In the last part of this study, marginal physical productivity (MPP) method, based on the response coefficients of the inputs, was utilized to evaluate the sensitivity analysis of energy inputs on the sugar beet yield and total GHG emission. Sensitivity analysis studies the relationship between information flowing and out of the model. The sensitivity measure is a linear estimate of the number of units changed in output data (i.e., the response variable) per unit of change in the results of the perturbed (Cariboni et al. 2007).

The MPP of the various inputs was computed using the *j* of the various energy inputs as follow (Pahlavan et al. 2011):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times \alpha_j \tag{10}$$

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$$MPP_{xj} = \frac{GM(GHG)}{GM(X_j)} \times \alpha_j \quad (11)$$

Where MPP_{xj} is the marginal physical productivity of j^{th} input, α_j denote the regression coefficient of j^{th} input, $GM(Y)$ is geometric mean of yield, $GM(GHG)$ is geometric mean of GHG emission and $GM(X_j)$ denote the geometric mean of j^{th} input energy on per hectare basis.

Basic information on energy inputs of sugar beet production were entered into Excel 2010 spreadsheets and SPSS 20.0 software program.

RESULTS AND DISCUSSION

Input-output energy use in sugar beet production

Table 3 offers a comprehensive summary of energy consumption in three farm sizes of sugar beet production in the surveyed region. The total energy used in the farm operations during sugar beet production and energy output was about 64920 and 1116742 MJ ha^{-1}, respectively. Erdal et al. (2007) reported the total energy inputs and yield of sugar beet was about 39685.51 MJ ha^{-1} and 1021776 kg ha^{-1} in Turkey, respectively. In another study, the total energy outputs and energy inputs of sugar beet production in Germany was calculated about 17300 and 261700 MJ ha^{-1}, respectively. These results indicated the energy consumption of sugar beet production in East Azerbaijan province of Iran had the high difference with rest of the world.

The results of this study revealed that there was no significant difference between all farms from output energy point of view; while the difference between total energy inputs was significant. Also, those in large farms, the application of energy inputs were significantly lower due to better management; while their yields were more than the two other groups, significantly. The energy consumptions of biocides in above-mentioned farms differ significantly. Additionally, it was found that less amount of energy was used for irrigation in small farms. It is due to the fact that in terms of a specific amount of water, less water is dissipated per hectare. It signifies that with the same total energy inputs the large farms produced more yield.

Table 3. Amounts of energy inputs and output in sugar beet production based on different farm size levels.

Items	Farm size groups (ha)			Average (MJ ha^{-1})
	Small (<2)	Medium (2-4)	Large (>4)	
A. Inputs				
1. Human labor	1814.34^{a}	1851.96^{ab}	1729.70^{b}	1819.13
2. Machinery	2037.75^{a}	2089.16^{b}	2218.01^{c}	2087.34
3. Diesel fuel	9764.67^{a}	9750.64^{ab}	9713.48^{b}	9750.84
4. Chemical fertilizers				
(a) Nitrogen	11995.39^{a}	11944.88^{a}	11822.53^{a}	11947.29
(b) Phosphate (P_2O_5)	2239.20^{a}	2281.50^{a}	2208.10^{a}	2253.90

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5. Farmyard manure	1344.55[a]	1334.40[b]	1297.50[c]	1333.09
6. Biocides	807.27[a]	820.80[b]	840.00 [c]	818.18
7. Electricity	24890.32[a]	24885.98[ab]	22965.25[b]	24608.34
8. Water for irrigation	10315.91[a]	10118.40[ab]	10072.50[b]	10190.73
9. Seed	110.23[a]	111.00[b]	112.50[b]	110.91
The total energy input	65319.62[a]	65188.72[b]	62979.56[c]	64919.75
B. Output				
Sugar beet	1087800.00[a]	1100736.00[b]	1145454.55[c]	1116741.82

Note: Different letters show significant difference of means at 5% level.

Figure 1 displays the share of each input in total energy consumption for sugar beet production in the studied area. Accordingly, the highest energy input is provided by electricity; followed by chemical fertilizers (mainly nitrogen). The main use of electricity was belonged to extraction of water for irrigation. The applying inappropriate electro pumps with high indicate power was the main reason of this result. Also, the wrong farm system and irregular utilization of chemical fertilizers for achieving more yields can reduce the energy efficiency in production of sugar beet in East Azerbaijan province, Iran.

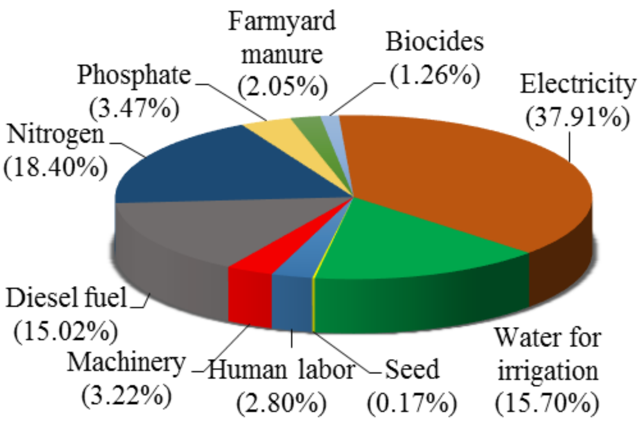

Figure 1. The share of energy inputs for sugar beet production in East Azerbaijan province, Iran.

3.2. Energy indices

Table 4 shows the energy use efficiency (energy ratio), energy productivity, specific and net energy for different area levels of sugar beet production. The average value of energy use efficiency was calculated as 17.20 which is significantly less than its amount found by Erdal et al. (2007). They reported that the energy ratio of sugar beet production was 25.75. As it can be observed, the energy ratio value of large farms with average value of 18.19 was significantly higher than its amount (16.65) in the small and medium farms. As the area of farms increased, energy productivity and net energy significantly increased simultaneously but specific energy decreased.

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Table 4. Energy input–output ratio in sugar beet production based on different farm size levels.

Items	Unit	Farm size groups (ha)			Average
		Small (<2)	Medium (2-4)	Large (>4)	
Energy use efficiency	-	16.65^{a}	16.89^{b}	18.19^{c}	17.20
Energy productivity	kg MJ^{-1}	0.99^{a}	1.01^{a}	1.08^{a}	1.02
Specific energy	MJ kg^{-1}	1.01^{a}	0.99^{a}	0.92^{a}	0.98
Net energy gain	MJ ha^{-1}	1022480.38^{a}	1035547.28^{b}	1082474.99^{c}	1051822.07

Note: Different letters show significant difference of means at 5% level.

Table 5. GHG emission of inputs in sugar beet based on different farm size levels.

Items	Farm size groups (ha)			Average ($kgCO_{2eq.}$ ha^{-1})
	Small (<2)	Medium (2-4)	Large (>4)	
1. Machinery	144.68^{a}	148.33^{b}	157.48^{b}	148.20
2. Diesel fuel	478.61^{a}	477.92^{a}	476.10^{a}	477.93
3. Chemical fertilizers				
(a) Nitrogen	235.77^{a}	234.78^{b}	232.38^{b}	234.83
(b) Phosphate (P_2O_5)	36.00^{a}	36.68^{b}	35.50^{c}	36.24
4. Biocides	25.56^{a}	25.99^{a}	26.59^{a}	25.90
5. Electricity	1268.51^{a}	1268.29^{b}	1170.40^{c}	1254.14
Total GHG emission	2189.13^{a}	2191.99^{a}	2098.45^{a}	2177.24

Note: Different letters show significant difference of means at 5% level.

GHG emission of sugar beet production

The results of GHG emission under three cultivated area are given in Table 5. Based on results, the total GHG emission was calculated as 2177.24 $kgCO_{2eq.}$ ha^{-1}. The ANOVA results showed the difference between three group farm sizes wasn't significant. As it can be seen in Table 5, the medium farms had the highest emission with 2191.99 $kgCO_{2eq.}$ ha^{-1}; while the lowest emission belonged to large farms with 2098.45 $kgCO_{2eq.}$ ha^{-1}. Obviously, the reason for this different was the consumption of electricity. With respect to above-mentioned, the reduction of electricity consumption can improve the emission in sugar beet production and save the natural resource for the next generations.

Yousefi et al. (2014) reported the total GHG emission of sugar beet production were about 2660 $kgCO_{2eq.}$ ha^{-1}. In similar results, they calculated the 73% of total GHG emission for electricity in Kermanshah province of Iran. The distribution of total GHG emission for each CO_2 emitter input in

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sugar beet production is shown in Figure 2. The results illustrated that the highest share of GHG emission for electricity with 57.60%; followed by diesel fuel with 21.95%. So, the selection of standard machinery can reduce the GHG emission in the studied area, significantly.

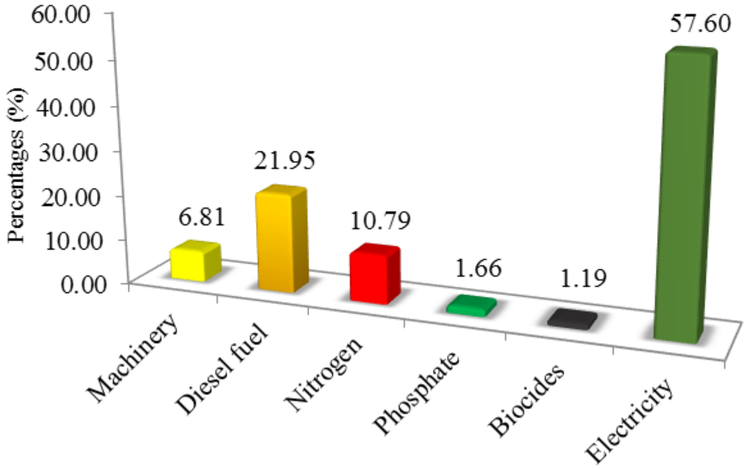

Figure 2. The share of inputs on GHG emission for sugar beet production.

Econometric models estimation

For investigating the relationship between the energy inputs with GHG emission and yield of sugar beet production, the Cobb-Douglas production function was specified and estimated using Ordinary Least Square (OLS) estimation technique. Therefore, it is assumed that the sugar beet yield and total GHG emission (endogenous variables) to be energy inputs (exogenous variables). For the data used in this study, presence of autocorrelation in the residuals from the regression analysis was tested using the Durbin-Watson statistic test (Rafiee e al., 2010). The test results revealed that Durbin-Watson values were as 1.93 and 2.28 and for yield and GHG emission models, respectively. These values indicated that there are no autocorrelation at the 1% significance level in the estimated models. The R^2 (coefficient of determination) was as 0.99 for both of linear regression models. The regression results of yield model revealed that the contribution of human labor and phosphate are significant at the 1% level. Also, the effect of nitrogen and diesel fuel is significant at the 5% level. Pishgar-Komleh et al. (2011) estimated an econometric model for corn silage production in Iran. They reported that the parameters of seed, fertilizer, machinery and diesel fuel had significant impacts in improving the yield of corn silage.

Moreover, the effects of machinery, diesel fuel, nitrogen, farmyard manure, biocides and electricity are significant at the 5% level in regression modeling of total GHG emission. The MPP value of models variables is shown in the last column of Table 6 and Table 7. As can be seen the MPP of biocides (with 26.68) and seed (with -0.2) had the highest for yield and GHG emission modeling, respectively. It should be noted, the MPP of seed in GHG emission modeling is declining.

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Table 6. Econometric estimation results of inputs.

Endogenous variable: Yield			
Items	Coefficient	*t*-ratio	MPP
Human labor	0.35	2.39**	12.80
Machinery	-0.02	-0.18	-0.64
Diesel fuel	0.43	3.11*	2.94
Nitrogen	0.37	4.29*	2.06
Phosphate	0.35	2.08**	10.32
Farmyard manure	0.12	1.02	6.04
Biocides	0.32	0.50	26.68
Electricity	0.33	0.40	0.91
Water for irrigation	0.38	3.21*	2.48
Seed	-0.02	-0.17	-12.03
Durbin-Watson	1.93		
R^2	0.99		
Return to scale ($\sum_{i=1}^{n}\alpha_i$)	2.61		

*, ** Indicates significance at 1% and 5% level, respectively.

Table 7. Econometric estimation results of inputs.

Endogenous variable: GHG emission			
Items	Coefficient	*t*-ratio	MPP
Human labor	0.01	0.97	0.01
Machinery	0.07	13.61*	0.07
Diesel fuel	0.24	28.13*	0.05
Nitrogen	0.12	11.65*	0.02
Phosphate	0.01	1.25	0.01
Farmyard manure	-0.02	-3.2*	-0.03
Biocides	0.01	3.4*	0.03
Electricity	0.57	113.26*	0.05
Water for irrigation	0.01	0.33	0.002
Seed	-0.01	-1.09	-0.20
Durbin-Watson	2.28		
R^2	0.99		
Return to scale ($\sum_{i=1}^{n}\alpha_i$)	1.01		

*, ** Indicates significance at 1% and 5% level, respectively.

CONCLUSION

In this study, the energy balance and GHG emission between the input and output for sugar beet production was investigated. The total energy consumption in sugar beet production was 64919.75

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MJ ha^{-1}. The energy input of electricity had the biggest share in the total energy inputs followed by water for irrigation and diesel fuel, respectively. The difference between energy use efficiency in three group size farms was significant and the large farms with the lowest total energy consumption were the highest sugar beet among all group. Also, the energy use efficiency was calculated as 17.20. With respect to GHG emission analysis, the total GHG emission was computed as 2177.24 $kgCO_{2eq.}$ ha^{-1} and electricity was the main CO_2 emitter input in sugar beet production. The difference between total GHG emission wasn't significant in three groups' farms. The highest emission belonged to electricity among all inputs followed by diesel fuel. The impact of human labor, nitrogen, diesel fuel and phosphate was significantly positive on yield and the contribution of machinery, diesel fuel, nitrogen, farmyard manure, biocides and electricity was significantly on GHG emission. The MPP value of biocides and seed energy inputs was the highest in yield and GHG emission model, respectively.

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REFERENCES

Anonymous (2012). Annual Agricultural Statistics. Ministry of Jihad-e-Agriculture of Iran. http://www.maj.ir, [in Persian].

Cariboni J., Gatelli D., Liskaa R. and Saltellia A. (2007). The role of sensitivity analysis in ecological modeling. *Ecological Modelling.* 203: 167-182.

Dyer J.A. and Desjardins R.L. (2006). Carbon dioxide emissions associated with the manufacturing of tractors and farm machinery in Canada. *Biosystems Engineering.* 93(1): 107-118.

Dyer J.A. and Desjardins R.L. (2003). Simulated farm fieldwork, energy consumption and related greenhouse gas emissions in Canada. *Biosystems Engineering.* 85(4): 503-513.

Erdal G., Esengun K., Erdal H. and Gunduz O. (2007). Energy use and economical analysis of sugar beet production in Tokat Province of Turkey. *Energy.* 32: 35-41.

Food and Agriculture Organization (2012). www.fao.org.

Ghorbani R., Mondani F., Amirmoradi S., Feizi H., Khorramdel S., Teimouri M., Sanjani S., Anvarkhah S. and Aghel H. (2010). A case study of energy use and economical analysis of irrigated and dryland wheat production systems. *Energy.* 88: 283-288.

Hatirli S.A., Ozkan B. and Fert C. (2005). An econometric analysis of energy input-output in Turkish agriculture. *Renewable and Sustainable Energy Reviews.* 9: 608-623.

Khoshnevisan B., Rafiee SH., Omid M., Yousefi M. and Movahedi M. (2013). Modeling of energy consumption and GHG (greenhouse gas) emissions in wheat production in Esfahan province of Iran using artificial neural networks. *Energy.* 52: 333-338.

Kizilaslan H. (2009). Input-output energy analysis of cherries production in Tokat Province of Turkey. *Applied Energy.* 86: 1354-1358.

Kuesters J. and Lammel J. (1999). Investigations of the energy efficiency of the production of winter wheat and sugar beet in Europe. *European Journal of Agronomy.* 11: 35-43.

ISSN: 2319–4731 (p); 2319–5037 (e)

Lal R. (2004). Carbon emission from farm operations. *Environment International.* 30 (7): 981-990.

Le Treut H., Somerville R., Cubasch U., Ding Y., Mauritzen C., Mokssit A., Peterson T. (2007). Prather M. Historical overview of climate change science. In: Climate Change 2007: the Physical Science Basis. Cambridge University Press.

Mobtaker H.G., Keyhani A., Mohammadi A., Rafiee S. and Akram A. (2010). Sensitivity analysis of energy inputs for barley production. *Agriculture, Ecosystems and Environment.* 137: 367-372.

Mohammadshirazi A., Akram A., Rafiee S., Mousavi-Avval SH. and Bagheri Kalhor E. (2012). An analysis of energy use and relation between energy inputs and yield in tangerine production. *Renewable and Sustainable Energy Reviews.* 16: 4515-4521.

Mousavi-Avval SH., Rafiee S., Jafari A. and Mohammadi A. (2011). Energy flow modeling and sensitivity analysis of inputs for canola production in Iran. *Journal of Cleaner Production.* 16:1464-1470.

Nabavi-Pelesaraei A., Abdi R., Rafiee S. and Mobtaker H.G. (2014a). Optimization of energy required and greenhouse gas emissions analysis for orange producers using data envelopment analysis approach. *Journal of Cleaner Production.* 65: 311-317.

Nabavi-Pelesaraei A., Abdi R., Rafiee S. and Taromi K. (2014b). Applying data envelopment analysis approach to improve energy efficiency and reduce greenhouse gas emission of rice production. *Engineering in Agriculture, Environment and Food.* http://dx.doi.org/10.1016/j.eaef.2014.06.001.

Nabavi-Pelesaraei A., Abdi R. and Rafiee S. (2013b). Energy use pattern and sensitivity analysis of energy inputs and economical models for peanut production in Iran. International *Journal of Agriculture and Crop Sciences.* 5(19): 2193-2202.

Nabavi-Pelesaraei A., Shaker-Koohi S. and Dehpour M.B. (2013a). Modeling and optimization of energy inputs and greenhouse gas emissions for eggplant production using artificial neural network and multi-objective genetic algorithm. *International journal of Advanced Biological and Biomedical Research.* 1(11): 1478-1489.

Pahlavan R., Omid M. and Akram A. (2011). Modeling and sensitivity analysis of energy inputs for greenhouse cucumber production. *Journal of Agricultural Technology.* 7(6): 1509-1521.

Pishgar-Komleh S.H., Keyhani A., Rafiee S. and Sefeedpari P. (2011). Energy use and economic analysis of corn silage production under three cultivated area levels in Tehran province of Iran. *Energy.* 36: 3335-3341.

Pishgar-Komleh SH., Omid M. and Heidari M.D. (2013). On the study of energy use and GHG (greenhouse gas) emissions in greenhouse cucumber production in Yazd province. *Energy.* 59: 63-71.

Rafiee S., Mousavi-Avval SH. and Mohammadi A. (2010). Modeling and sensitivity analysis of energy inputs for apple production in Iran. *Energy.* 35: 3301-3306.

Reineke H., Stockfisch N. and Märländer B. (2013). Analysing the energy balances of sugar beet cultivation in commercial farms in Germany. European Journal of Agronomy 45: 27-38.

Royan M., Khojastehpour M., Emadi B. and Mobtaker H.G. (2012). Investigation of energy inputs for peach production using sensitivity analysis in Iran. *Energy Conversion and Management.* 64: 441-446.

ISSN: 2319–4731 (p); 2319–5037 (e)

Soheili-Fard F., Ghassemzadeh H.R. and Salavatian S.B. (2014). An investigation of relation between CO_2 emissions and yield of tea production in Guilan province of Iran. *International Journal of Biosciences.* 4(11): 178-185.

Soni P., Taewichit C. and Salokhe V.M. (2013). Energy consumption and CO_2 emissions in rainfed agricultural production systems of Northeast Thailand. *Agricultural Systems.* 116: 25-36.

Tzilivakis J., Warner D.J., May M., Lewis K.A. and Jaggard K. (2005). An assessment of the energy inputs and greenhouse gas emissions in sugar beet (*Beta vulgaris*) production in the UK. *Agricultural Systems.* 85: 101-119.

Unakitan G., Hurma H. and Yilmaz F. (2010). An analysis of energy use efficiency of canola production in Turkey. *Energy.* 35: 3623-3627.

Yousefi M., Khoramivafa M. and Mondani F. (2014). Integrated evaluation of energy use, greenhouse gas emissions and global warming potential for sugar beet (*Beta vulgaris*) agroecosystems in Iran. *Atmospheric Environment.* 92: 501-505.

