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A comparative study on energy inputs and yield of canola production under different environmental conditions

Zeynab Ramedani*, Mahmoud Omid, Faezeh Fahimi and Farzad Mirzaee

Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

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The energy consumption and sensitivity analysis for inputs for canola production in Iran for two climateorological conditions (Qom city with dry climate and Kordkuy city with humid climate) were determined. Data were collected from 30 and 35 producers in Qom and Kordkuy cites by using face to face questionnaire method. The results indicated that total energy consumed in Qom and Kordkuy were 111926.53 MJ/ ha and 27059.89 MJ/ ha, respectively. The net energy of canola production for Qom city was -28810 MJ/ ha while this value for Kordkuy was 44538.51 MJ/ ha. The energy ratios were 0.74 and 2.65 and the ratio of direct to indirect energy forms were 90:10 and 70:30 in Qom and Kordkuy, respectively. The evaluation of econometric model showed that the impact of seed and diesel fuel were significant at level of 1%, for both two climateorological conditions. The sensitivity analysis indicated that with increasing energy of 1 MJ in seed or diesel fuel yield increased by ratio of 13.45 and 31.35 in Qom and Kordkuy, respectively.

Key words: Canola, Energy ratio, MPP sensitivity analysis, Direct energy, Renewable energy

Introduction

Rapeseed or canola is a member of the cabbage family (Brassicas or Crucifers), which also contains plants, such as mustard, turnips, and kale (FAO, 2008). The word of canola is derived from Canadian Oil, Low Acid and was registered in Canada in 1970 (Australian Health and Ageing Department, 2008). Canola containing less than 2% erucic acid as percentage of the fatty acids in the oil and less than 30 mmol/g of glucosinolate in the oil–free meal (Bell, 1993). China, Canada and India are main producer of this crop in the word. The harvested area of canola in 2009 was 137,000 ha and the production quantity was 264,000 tons with average yield of 1.9 tons per hectare (Iran Agricultural Ministry, 2009). Canola is cultivated in different climates in Iran

* Corresponding Author: Zeynab Ramedani; e-mail: zeynabramedani@ut.ac.ir

such as Qom city (in the middle of Iran) with dry and hot climate and Kordkuy city (in the north of Iran) with humid climate with mild winters.

Energy is used in all facets of living and in all countries, and makes possible the existence of ecosystems, human civilizations and life itself (Ramedani *et al.* 2011). Different regions and societies adapt to their environments and determine their own energy resources because it is a fundamental part of economic development. Given the growing population's food requirements, the finite supply of fossil fuels and the adverse environmental impacts of using this non–renewable resource, the existing relationship between agriculture and energy must be dramatically altered. This relation between agriculture and energy should be detected. Agriculture itself is an energy user and energy supplier in the form of bio–energy (Alam *et al.* 2005).

Numerous researches have been conducted on energy analysis for determining the energy efficiency, such as soybean (Ramedani *et al.* 2011; Taheri–Garavand *et al.* 2010), grape (Rajabi Hamedani *et al.* 2011), lentil (Mirzaee *et al.* 2011) and greenhouse vegetables (tomato, cucumber, eggplant, pepper and basil) (Ozkan *et al.* 2004a; Canakci and Akinci, 2006; Omid *et al.* 2011; Pahlavan *et al.* 2012). However, few studies have been published on the energy analysis of a crop production in different climateorological conditions.

Therefore, this study was done with the following objectives, estimating energy consumption in canola production in Qom city with hot and dry climate, and Kordkuy city with humid and moderate climate, determining and comparing the energy output–input ratio and other energy indices in these regions, and analyzing the relationship between energy inputs and yield, by developing mathematical models based on Cobb–Douglas production function for canola farms in Qom and Kordkuy cities.

Material and methods

The study was done in Qom and Kordkuy cites, the most cultivated area of canola production in Qom and Golestan provinces, respectively. Qom is located in the middle of Iran with dry climate at the longitude of 50°88′and latitude of 34°65′, whereas Kordkuy is located in the north of Iran with humid and moderate at the longitude of 54°1′and latitude of 36°8′. The cultivation area of canola in Qom and Golestan provinces are 1346 ha and 33186 ha, respectively (Iran Agricultural Ministry, 2009). The data were collected from 30 and 35 canola farms in Qom and Kordkuy cities, respectively using face to face questionnaire method during the January and February 2011. The collected data were belonged to the production period of 2010–2011.For determining the farm numbers, the Neyman method and stratified random sampling technique were applied using the following formula (Yamane, 1967):

$$n = \frac{\sum N_h S_h}{N^2 D^2 + \sum N_h S_h^2} \qquad (1)$$

where 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 stratified, S_h^2 is the variance of the h stratified, d is the precision where ($\bar{x} - \bar{X}$), z is the reliability coefficient (1.96 which represent the 95% reliability) and $D^2 = d^2/z^2$. To calculate the sample size, permissible error of 5% within confidence level of 95% was used. Therefore the size of 30 and 35 was obtained as sampling size in the Qom and Kordkuy, respectively. Accordingly, data on 30 and 35 canola farms in the Qom and Kordkuy were selected randomly.

The amount of rainfall in north of Iran such as Kordkuy, is good, hence canola tilt in dry farming method in this region. However, in dry areas such as Qom province cultivation of whole crops is based on irrigation farming method. In order to calculate the input–output and order energy indicators, the data were converted into output and input energy level using equivalent energy values for each commodity and input. Energy equivalents which are shown in Table 1, were used for estimation. It should be noted that for calculating the energy inputs and output of each canola farm, all of them must be quantified on a per unit (e.g. hectare) basis. In this research different energy inputs were investigated. The common energy inputs were human labor, machinery, diesel fuel, seed, chemicals and chemical fertilizers and energy output was the yield value of canola. However, water for irrigation and electricity were used as additional energy inputs in Qom city. Also Qom farmers used fungicides as chemical materials in their farms.

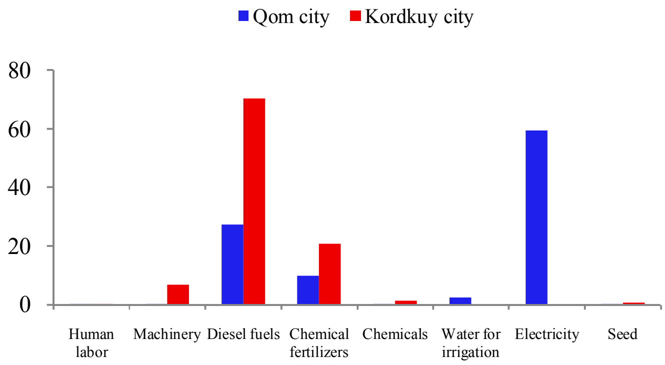

Fig. 1. The share of total mean energy inputs in canola production

Table 1. Energy equivalents of inputs and output in canola production

Inputs	**Unit**	**Energy equivalent (MJ ha^{-1})**	**Reference**
Inputs			
Human labor	h	1.96	(Yilmaz *et al.*, 2005)
Machinery	h	62.7	(Canakci and Akinci, 2006)
Diesel fuel	L	56.31	(Singh, 2002; Ozkan *et al.*, 2004b)
Chemical fertilizers			
Nitrogen (N)	kg	66.14	(Yilmaz *et al.*, 2005; Singh, 2002; Kizilaslan, 2009)
Phosphate (P_2O5)	kg	12.44	(Yilmaz *et al.*, 2005; Singh, 2002; Kizilaslan, 2009)
Potassium (K2O)	kg	11.15	(Yilmaz *et al.*, 2005); Kizilaslan, 2009)
Chemicals			
Herbicides	kg	238	(Ramedani *et al.*, 2011)
Insecticides	kg	101.2	(Ramedani *et al.*, 2011)
Fungicides		216	(Ramedani *et al.*, 2011)
Water for irrigation	m^3	1.02	(Omid *et al.*, 2011)
Electricity	kWh	11.93	(Omid *et al.*, 2011;Ozkan *et al.*, 2004b)
Seeds	kg	29.2	(Rowsell *et al.*, 2007)
Output			
Canola	kg	29.2	(Rowsell *et al.*, 2007)

Production energy of tractors and agricultural machines per unit area were calculated by using the following equation (Ozkan *et al.* 2007).

$$ME = E\frac{G}{T} \qquad (2)$$

where ME is the machinery energy (MJ/ h), E (=62.7 MJ/ kg) the production energy of machine, G the weight of machine (kg), and T is the economic life of machine (h).

The energy ratio (energy use efficiency) is used to describe the relationship between energy output of a system and the energy inputs needed to operate it. An increasing in the energy ratio indicates improvement in energy efficiency with good environmental performance and vice versa. In this study, energy ratio, energy productivity, specific energy and net energy were calculated using the following equations (Ramedani *et al.* 2011; Demircan *et al.* 2006):

$$EnergyRatio = \frac{EnergyOutput(MJ/ha)}{EnergyInput(MJ/ha)} \quad (3)$$

$$EnergyProductivity = \frac{CanolaOutput(kg/ha)}{EnergyInput(MJ/ha)} \quad (4)$$

$$SpecificEnergy = \frac{EnergyInput(MJ/ha)}{CanolaOutput(kg/ha)} \quad (5)$$

$$NetEnergy = EnergyOutput(MJ/ha) - EnergyInput(MJ/ha) \quad (6)$$

The input energy is also classified into direct and indirect, also renewable and non-renewable forms for different inputs and outputs in agricultural production (Mandal *et al.* 2002; Hatirli *et al.* 2005). Indirect energy (IDE) consists of seeds, chemical fertilizers, chemicals and machinery energy while direct energy (DE) covered human labor, water for irrigation, electricity and diesel fuel used in the canola production. Non-renewable energy (NRE) includes diesel fuel, electricity, chemicals, chemical fertilizers and machinery, while renewable energy (RE) consists of human labor, seeds and water for irrigation.

In order to analyzing the relationship between energy inputs and yield several mathematical functions were tried. Cobb–Douglas function yielded better estimates in terms of statistical significance and expected signs of parameters among linear, linear–logarithmic, logarithmic–linear and second degree polynomial functions. In the literature, Cobb–Douglas function has been used by several authors to examine the relationship between energy inputs and production or yield (Hatirli *et al.* 2005). Cobb–Douglas production function is expressed as:

$$Y = f(x)\exp(u) \quad (7)$$

Equation (7) can be linearized and expressed in the following form as:

Model I: $\ln Y_i = a + \sum_{j=1}^{n} a_j \ln(X_{ij}) + e_i \qquad i=1, 2, \ldots, n$ (8)

where Y_i denotes the yield of the ith farmer, X_{ij} the vector of inputs used in the production process, a the constant term, j represent coefficients of inputs which are estimated from the model and e_i is the error term. With assumption that, when the energy input is zero, the crop production is zero, Eq. (8) changed to Eq. (9) as:

$$\ln Y_i = \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \qquad i=1, 2, \ldots, n \tag{9}$$

With assumption that yield is a function of inputs energy, Model I can be expanded to Eq. (9) as in Eq. 10a for Qom and Eq. 10b for Kordkuy:

$$\ln Y_i^Q = \alpha_1 \ln(X_1) + \alpha_2 \ln(X_2) + \alpha_3 \ln(X_3) + \alpha_4 \ln(X_4) + \alpha_5 \ln(X_5) + \alpha_6 \ln(X_6) + \alpha_7 \ln(\tag{10a}$$

$$\ln Y_i^K = \alpha_1 \ln(X_1) + \alpha_2 \ln(X_2) + \alpha_3 \ln(X_3) + \alpha_4 \ln(X_4) + \alpha_5 \ln(X_5) + \alpha_6 \ln(X_6) \tag{10b}$$

where X_1 is seed energy, X_2 human labor energy, X_3 machinery, X_4 diesel fuel, X_5 chemical fertilizers, X_6 chemicals, X_7 water for irrigation and X_8 electricity is energy inputs.

The analyzing the relationship between forms of energy and canola yield, Cobb–Douglas function was used to evaluate the impact of direct, indirect, renewable and non–renewable energy as following forms (Mobtaker *et al.*, 2010):

Model II: $\ln Y_i = \beta_0 + \beta_1 \ln DE + \beta_2 \ln IDI + e_i$ (11)

Model III: $\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$ (12)

where Y_i is the ith farmer's yield, β_i and γ_i are coefficient of exogenous variables. DE and IDE are direct and indirect energies, respectively, RE is renewable energy and NRE is non–renewable energy.

The marginal physical productivity (MPP) technique, based on the response coefficients of the inputs, was used to determine the sensitivity of a particular energy input to production. The MPP of a factor indicates the change in the total output as a result of per unit change in that input factor in question, keeping all other factor constant at their geometric mean level (Manes and Singh, 2005). In other words MPP is the extra output generated by an extra input. It is not necessary to increase the quantity of a factor of production exactly by 1 unit to find out marginal physical product. We can find out the increase in production corresponding to any small increase in the quantity of factor of production. MPP is found by dividing the change in total physical product by the change in the variable input as follows:

$$MPP_{xj} = \frac{GM(P)}{GM(E_j)} \times \alpha_j = \frac{GM(Y)}{GM(X_j)} \times \alpha_j \qquad (13)$$

where MPP_{xj} is marginal physical productivity of *j*th input, α_j is regression coefficient of *j*th input, *GM(P)* is geometric mean of production, $GM(E_j)$ is geometric mean of *j*th input on farm ($E_{ji} = X_{ij}A_i$), *GM(Y)* is geometric mean of productivity and $GM(X_j)$ geometric mean of *j*th input on per hectare basis.

Finally, the concept and application of return to scale (RTS) would be described. RTS refers to change in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). In the Cobb–Douglas production function, it is indicated by the sum of the elasticity which derived in the form of regression coefficients. If the sum of the coefficients is greater than unity ($\sum_{i=1}^{n} \alpha_j > 1$), then it could be concluded that the increasing returns to scale (IRS). That means an increasing in inputs may result in an increasing in output in greater proportion than the input increase. If the function becomes less than unity ($\sum_{i=1}^{n} \alpha_j < 1$), then it is indicated that the decreasing returns to scale (DRS). That means an increasing in inputs may result in an increasing in output in less proportion than the input increase; and if the sum is equal to one ($\sum_{i=1}^{n} \alpha_j = 1$), it shows that the constant returns to scale; this implies despite changing inputs and the output is constant.

Basic information on energy inputs and canola yields were entered into Excel's spreadsheet and simulated using Shazam 9.0 software.

Results and discussions

Analysis of input–output energy consumption in canola production

The values of inputs and output parameters and their energy equivalents used in canola production in mentioned areas are shown in Table 2. Average canola yield in Qom and Kordkuy were about 2875 kg/ ha and 2452 kg/ ha, respectively. The total energy equivalents of the inputs and output were calculated by multi–plying the quantity per unit area by their equivalent energy. The total energy requirements for canola production were 111926.53 MJ/ ha and 27059.89 MJ/ ha in Qom and Kordkuy, respectively. Energy consumption in Qom was about 4 times in Kordkuy. This is due to environment condition; one of main factors in energy consumption is water requirement, because in high temperatures and dry air, water needs to increase.

Due to good rains in northern Iran, winter crops such as canola cultivation can be done without irrigation and these two factors caused a sharp difference in energy consumption in these two zones. The energy use pattern is shown in Fig.1. Among the different energy sources electricity and diesel fuel was the highest energy consumer for Qom and Kordkuy, respectively. The consumption of electricity and diesel fuel energy in middle and north of Iran were found with a share of 59.47% and 70.35%, respectively. Most irrigation pumps in Qom city and its margins are electrical and this is reason for the high consumption of this energy input. The majority of diesel fuel that is situated in first and second level among total energy input in Kordkuy and Qom cities was used for soil preparation. It showed that human labor were the least demanding energy input with 124.54 MJ/ ha (0.11%) and 25.18 MJ/ ha (0.09%) as shown in Table 2. Because canola is cultivated with drill seeder in a large area and weeding is not occur in cultivation period, hence human labor energy has the lowest value among total energy inputs.

The energy use efficiency, specific energy, energy productivity and net energy of canola were calculated using Eqs. (3)–(6) and the results are presented in Table 3. Energy use efficiency (energy ratio) in Qom city was 0.74, while this value was 2.65 in Kordkuy city. Also the values of specific energy, energy productivity and net energy were 0.03 MJ/ kg, 39.22 kg/ MJ and -28810 MJ/ ha in Qom and 0.09 MJ/ kg, 11.04 kg/ MJ and 44538.51 MJ/ ha respectively in Kordkuy. Based on the results, by increasing the annual yield of canola production and/or decreasing the energy consumption, especially diesel fuel energy, canola production in north of Iran would be efficient. While high EC (salt) level of soil with low amount in nutrients caused that cultivation of this crop in Qom city was not to be efficient.

Table 2. Energy use pattern for canola production

Input/output (unit)	Canola in Qom TEE		Canola in Kordkuy TEE	
	(MJ ha^{-1})	%	(MJ ha^{-1})	%
A. Inputs				
Human labor	124.54	0.11	25.18	0.09
Machinery (h)	103.19	0.09	1835.44	6.78
Diesel fuel (l)	30829.81	27.34	19035.60	70.35
Water for irrigation (m^3)	3010.95	2.67	0	0
Electricity (kWh)	67057.85	59.47	0	0
Seed (kg)	313.9	0.28	204.98	0.76
Chemicals (kg)	447.3	0.40	334.46	1.24
Chemical fertilizer	10934.72	9.70	5624.23	20.78
Nitrogen (kg)	9254.09	8.21	5099.13	18.84
Phosphate (kg)	1037.19	0.92	312.82	1.16
Potassium (kg)	643.45	0.57	212.27	0.78
Total Energy input (MJ/ha)	111926.53	100	27059.89	100
B. Output				
Soybean (kg)	83950		71598.4	

Table 3. Energy indices and forms of inputs energy

Items	Unit	Canola in Qom	%	Canola in Kordkuy	%
Energy efficiency	----	0.74		2.65	
Specific energy	MJ kg^{-1}	0.03		0.09	
Energy productivity	kg MJ^{-1}	39.22		11.04	
Net energy	MJ ha^{-1}	-28810		44538.51	
DE[a]	MJ ha^{-1}	101023	90	19060.78	70
IDE[b]	MJ ha^{-1}	11737	10	7999.11	30
RE[c]	MJ ha^{-1}	3449.4	3	230.16	1
NRE[d]	MJ ha^{-1}	109310	97	26829.73	99

[a] Includes electricity, human labor, diesel fuel, water for irrigation, [b] Includes seed, fertilizers, chemicals, machinery, [c] Includes seed, human labor, water for irrigation, [d] Includes diesel fuel, electricity, chemicals, fertilizers, machinery.

Econometric model estimation of canola production

The relationship between energy inputs and canola yields were estimated by CD production function (Model I) and using ordinary least square (OLS) estimation technique. Accordingly, the yield of canola in Qom city (endogenous variable) was assumed to be a function of human labor, machinery, diesel fuel, fertilizers, chemicals, water for irrigation, electricity and seed energy (exogenous variables). It could be stated that the yield of canola in Kordkuy city is a function of human labor, machinery, diesel fuel, fertilizers, chemicals and seed energy. Autocorrelation test was performed using Durbine Watson (DW) test (Hatirli *et al.* 2005; Mobtaker *et al.* 2010). The results indicated that DW values of canola in Qom and Kordkuy were 1.68 and 1.87 respectively for Model I, i.e. there was no autocorrelation at the 5% significance level in the estimated models. The R^2 coefficient for canola was as 0.99 for this linear regression model in both regions, which revealed variability of this model in the energy inputs. The result of regression for this model is shown in Table 4 that in Qom, seed had the highest impact (1.5) among other inputs and significantly contributed on the yield at 1% level. This indicated that with an additional use of 1% for of this input would lead to 1.5% increase in canola yield. The other important inputs were machinery at 5% level. Regression results in Kordkuy (Table 4) revealed that, diesel fuel had the highest significantly as 0.91. Also machinery was other significant inputs significant at 5% level for canola production in this region. Ramedani *et al.* (2011) estimated an econometric model for soybean production in Iran. They reported that the inputs of seed had significant impacts on improving the yield of soybean.

The relationships between the direct (DE) and indirect (IDE) energy, as well as renewable (RE) and non–renewable (NRE) energy on yield of each greenhouse production were investigated by Eqs. (11) and (12) (Models II and III), respectively. The results are presented in Table 5. It can be seen that, except IDE all the other regression coefficients of DI, RE and NRE forms were positive at significant ($p < 1\%$) in Kordkuy city. The regression coefficients of DE and IDE Qom city were also significant ($p < 1\%$). Among all regression coefficients, the coefficient of NRE in Qom city was significant in 5% level. Other regression coefficients e.g. IDE for Kordkuy and RE for Qom were insignificant ($p > 5\%$). The impact of IDE was more than the impact of DE on yield in Qom city. Similar results can be seen in the study of Hatirli *et al.* (2005) for greenhouse tomato production. Also the impact of NRE was more than the impact of RE on yield in Kordkuy city. Statistical tests revealed that DW values were 1.54–1.65 for Model II, which indicated that there is no autocorrelation at the 5% significance level in the estimated models. These results for Model III were 1.88 at the 5% significance level for both mentioned regions.

Table 4. Econometric estimation and sensitivity analysis results of inputs for canola in Qom city and city of Kordkuy based on model I

Endogenous variable:	**Canola yield in Qom**			**Canola yield in Kordkuy**		
Exogenous variables	Coefficient	t–ratio	MPP	Coefficient	t–ratio	MPP
1. Seed (α_1)	1.50	4.37**	13.45	0.15	1.02	1.80
2. Human labor (α_2)	0.1	0.46	2.69	0.32	1.24	31.35
3. Machinery (α_3)	-0.53	-2.19*	-15.15	-0.32	-2.46*	-0.92
4. Diesel fuel (α_4)	0.05	0.58	0.01	0.91	3.83**	0.13
5. Chemical Fertilizers (α_5)	0.5	0.26	0.01	0.05	0.31	0.02
6. Chemicals (α_6)	-0.02	-0.13	-0.13	-0.21	-1.87	-1.56
7. Water for irrigation (α_7)	-0.10	-0.42	-0.10	----	0	----
8. Electricity (α_8)	0.11	0.9	0.01	----	0	----
Durbin-Watson	1.68			1.87		
R^2	0.99			0.99		
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	1.16			0.91		

*Significance at 1% level.
**Significance at 5% level.

Sensitivity of energy inputs, DE, IDE, RE and NRE

The last column of Table 4 for each region shows the MPP value for all inputs. As it can be seen, in Qom city seed had the highest MPP value (13.45) and followed by human labor (2.69). Based on the results, 1 MJ growth in using each of seed and human labor inputs, lead to 13.45 kg/ ha and 2.69 kg/ ha increasing in canola production. Singh *et al.* (2004) examined the sensitivity of energy inputs on wheat productivity for five agro–climate zones in India. They reported that MPP of chemicals in zones 1–5 which were calculated to be 0.385, 2.816, -0.211, 0.610 and 0.624, respectively.

Similar results for Kordkuy city were obtained. In Kordkuy city Human labor had the highest MPP value (31.35) and followed by seed (1.80). Results indicated that, 1 MJ growth in using each of human labor and seed inputs, lead to 31.35 kg/ ha and 1.80 kg/ ha increasing in canola production. Mobtaker e al. (2010) analyzed the sensitivity of energy inputs on barley productivity. They reported that the major MPP was due to human labor energy (7.37), followed by machinery energy (1.66).

The MPP values of direct, indirect, renewable and non–renewable energy were 0.01, 0.11, 0.37 and 0.01, respectively in Qom city and 0.16, -0.10, 4.81 and 0.05 in Kordkuy city as shown in Table 5. It indicated that an additional use of 1 MJ in each of the direct, indirect, renewable and non–renewable energy, would lead to an additional increase in yield by 0.01, 0.11, 0.37 and 0.01kg/ ha, respectively in Qom city. These results can be enhanced about MPP sensitivity analysis in Kordkuy city.

The return to scale (RTS) values for Models I to III (Eqs. (8), (11) and (12)) were calculated by gathering the regression coefficients and shown in Tables 4 and 5. RTS values of Model I, canola yields were 1.16 and 0.91, in Qom Kordkuy, respectively. Thus, it showed an IRS of canola in Qom city for estimated model. The higher values of RTS than unity in Qom city indicated IRS, whereas the lower value than unity in Kordkuy revealed a DRS. This revealed that 1% increase in the total energy inputs utilize would lead in 1.16% increase in the yield for this model in dry region. The RTS values in Model II and for Model III were all IRS, but in Model III it was DRS in both regions (Table 5).

Table 5. Econometric estimation of direct (DE) vs. indirect (IDE) based on model II, and renewable (RE) vs. non-renewable (NRE) based on model III

Endogenous variable:	**Canola yield in Qom**			**Canola yield in Kordkuy**		
Exogenous variables	Coefficient	t–ratio	MPP	Coefficient	t–ratio	MPP
1. DE	0.34	2.88**	0.01	1.11	6.73**	0.16
2. IDE	0.44	3.09**	0.11	-0.31	-1.87	-0.10
Durbin–Watson	1.65			1.54		
R^2	0.99			0.99		
Return to scale ($\sum_{i=1}^{n} \beta_i$)	0.78			0.75		
1. RE	0.42	1.95	0.37	0.45	3.2**	4.81
2. NRE	0.40	2.64*	0.01	0.53	7.13**	0.05
Durbin–Watson	1.88			1.88		
R^2	0.99			0.99		
Return to scale ($\sum_{i=1}^{n} \gamma_i$)	0.81			0.98		

*Significance at 1% level.
**Significance at 5% level.

Conclusion

In this study, the energy balance between the input and output for canola production was investigated in Qom and Kordkuy cities in middle and north of Iran, respectively. The total energy consumption in canola production was 111926.53 MJ/ ha and 27059.89 MJ/ ha in Qom and Kordkuy cities, respectively. The energy input of electricity and diesel fuel had the biggest share within the total energy inputs in Qom and Kordkuy, respectively and followed by machinery in both regions. Approximately 90% of total energy input used in canola production was directed in middle of Iran, while this value was 70% in north of Iran. Also the ratio of renewable: non–renewable energy inputs were 3:97 in Qom and 1:99 in Kordkuy. The impact of seed and machinery energy inputs was significantly positive and negative on yield respectively in Qom city and the impact of diesel fuel and machinery energy inputs was significantly positive and negative on yield respectively in Kordkuy city. The MPP value of seed and human labor was the highest in hot and middle climateorological condition. Energy management becomes more important when the required energy should be economical, sustainable and productive.

Results showed that reduce in diesel electricity, diesel fuel and fertilizer consumptions are important for energy saving and decreasing the environmental risk problem in the area. High inputs of electricity, diesel fuel and the other NREs based on fossil fuel resources would result in more emissions of carbon dioxide, a major greenhouse gas contributing to global warming with extensive impacts on environment. One of the main reasons for high consumption of diesel fuel is temporal depreciation of machinery particularly in tractors. Since electric pumps are old, high level of electricity energy is used.

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