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INFORMATION PROCESSING IN AGRICULTURE 5 (2018) 114–123

journal homepage: www.elsevier.com/locate/inpa

Sensitivity analysis of energy inputs and economic evaluation of pomegranate production in Iran

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A R T I C L E I N F O

Article history:
Received 27 November 2016
Received in revised form
21 September 2017
Accepted 24 October 2017
Available online 14 November 2017

Keywords:
Benefit to cost
Cobb-Douglas
Energy modeling
Energy pattern
Pomegranate

A B S T R A C T

The aim of this research was to investigate the energy use and costs of pomegranate production in Behshahr city (Mazandaran province) of Iran. The required data were gathered by questionnaire and face to face interviews with 83 pomegranate producers. Cobb-Douglas model and sensitivity analysis were employed for energy flows modeling of the production system. The total energy inputs and energy output of production were determined to be 11195.06 and 13276.56 MJ ha^{-1}, and two inputs of diesel fuel and chemical fertilizers with the shares of 45.81 and 23.47%, were the highest energy consumers for pomegranate production. Energy use efficiency, energy productivity and net energy were 1.18, 2081.50 MJ ha^{-1} and 0.62 kg MJ^{-1}, respectively. The results of Cobb-Douglas model showed that the effect of the energy inputs including human labor, biocides, chemical fertilizers, farmyard manure, electricity and water for irrigation on pomegranates yield were positive, while the effects of diesel fuel and agricultural machinery were negative on the pomegranate yield. The sensitivity analysis results of energy inputs showed that with the increase of one MJ in the energy input of water for irrigation and chemical fertilizers, the yield was increased to 3.12 and 1.42 kg, respectively. Also with the increase of one MJ in diesel fuel and agricultural machinery inputs, the yield was decreased to 0.67 and 0.47 kg, respectively. Diesel fuel as the most used energy input in the production accounted for 0.85% of variable costs and the benefit to cost ratio was determined to be 5.57.

1. Introduction

Energy is one of the most important factors for sustainability evaluation of agricultural production systems [1]. Today, a considerable portion of energy is used to mechanize agricultural operations and the excessive costs are spent to provide the required power on agricultural mechanization. Nowadays, developed countries try to optimize agricultural production systems concerning energy consumption by investigating energy input in the area unit of agricultural production and also by analyzing energy indicators in the agricultural production area. The efficient use of energy could develop the sustainable agriculture by reducing environmental impacts and preventing destruction of natural [2].

Pomegranate is the native fruit of eastern part of Iran to Himalaya Mountains in north of India, and has been cultivated in the whole Mediterranean region and Caucasus in Asia during Ancient Times. Countries such as Iran, Tunisia, Turkey, Spain and USA are the leading countries in the production of pomegranates in the world [4]. Annually about three million tons of pomegranates are produced in the world

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Peer review under responsibility of China Agricultural University.
https://doi.org/10.1016/j.inpa.2017.10.002
2214-3173

and Iran is the first producer by producing about nine hundred and forty thousand tons of this fruit [4]. Mazandaran province is located in the north of Iran across the Caspian Sea, in which pomegranate is one of the most important fruits produced in this province. The area under the cultivation of pomegranate in Iran was about 82,500 hectares in 2013 from which 66,000 hectares have been fertile and productive. Mazandaran province is one of the largest producers of pomegranate with about 1200 hectares under cultivation and producing 9600 tons pomegranates in 2013 [5].

Several studies have been done on the energy use pattern of fruit production. The analysis of energy use pattern for the production of peach production system [6]. They reported that the total energy consumption for the production of peach was 37,537 MJ ha^{-1} and diesel fuel with the amount of 26.32% was the primary source of input energy. In another research, the analysis of energy consumption and sensitivity analysis of energy inputs for the production of pear were investigated [7]. The results showed that the total energy input for the production of pear was 172,608 MJ ha^{-1} and electricity with 77.86% had the most energy consumption. The benefit to cost ratio was reported 3.11 and the human labor with 33% portion of the total costs had the highest cost among other inputs. There are some published documents about energy use pattern of some fruits production systems such as citrus [8], nectarine [9] and kiwifruit [10].

The literature review showed that only two published studies have addressed the energy use pattern of pomegranate production. Akcaoz et al. [3] studied energy use pattern for production of pomegranate in Antalya province of Turkey and the total amount of energy input was reported 53,765 MJ ha^{-1}. Chemical fertilizer energy input was reported as the most energy consumer with the amount of 40%. Net energy and energy efficiency were also reported 2275.37 MJ ha^{-1} and 1.04, respectively. Direct energy was accounted for 84% of the total input consumption. Meanwhile, renewable energy was accounted for 89.93% of the total energy input. In another study, Canakci analyzed the energy consumption of pomegranate production system in Antalya province of Turkey [11]. This researcher collected the data from 92 orchards of three areas located in coastal to mountainous areas which had different soil and geographic characteristics. His findings showed that the energy consumption was ranged between 32,619 and 44,463 MJ ha^{-1} and the energy efficiency in those areas was alternating between 1.14 and 1.25.

The related literature review indicated that a comprehensive and inclusive research on the energy use pattern modeling and input costs of pomegranate production has not been investigated. Therefore, the aim of this study was to model the energy use pattern and costs of pomegranate production through Cobb-Douglas model. In addition, marginal physical productivity (MPP) approach was used to sensitivity analysis of energy inputs.

2. Materials and methods

2.1. *Case study and data collection*

The study area was Behshahr city of Mazandaran. This city is located within 36°20′ and 36°53′ north latitude and 53°14′ and 54°7′ east longitude. Behshahr city has moderate mountainous weather with the average daily temperature, rainfall, humidity, highest yearly temperature and minimum temperature of 17.3 °C, 5096 mm, 79%, 46 °C and 4 °C, respectively. Research population included all pomegranate growers in Behshahr city during 2012–2013 growing season. Sample size was determined using Cochran formula (Eq. (1)) [12]. Accordingly, 83 pomegranate orchards were determined.

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

$$d = \frac{t \times s}{\sqrt{n}} \tag{2}$$

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 the target population and d is the acceptable error (permissible error 5%) (Eq. (2)). For the calculation of sample size, the criteria of 5% deviation from population mean and 95% confidence level were used.

2.2. *Energy analysis*

In this study, eight energy inputs, including human labor, machinery, diesel fuel, chemical fertilizers, biocides, water for irrigation, farmyard manure and electricity were considered. In Table 1, the energy coefficients were shown for different inputs used in the study. The energy associated with each input was determined through multiplying the amount of input consumption data (collected through interviews) by an energy coefficient [13–15]. The biocides were divided into three groups including herbicides, fungicides and insecticides to obtain the energy amount of these materials [16]. The equivalent coefficient of electricity was also calculated according to the efficiency of electricity production at power-plants and the efficiency of transmission and distribution network [16].

Then, energy indices including energy ratio, energy productivity, specific energy and net energy were determined according to the Eqs. (3)–(6) [17,18].

$$\text{Energy ratio} = \frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \tag{3}$$

$$\text{Energy productivity} = \frac{\text{Pomegranate yield (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \tag{4}$$

$$\text{Specific energy} = \frac{\text{Energy Input (MJ ha}^{-1})}{\text{Pomegranate yield (kg ha}^{-1})} \tag{5}$$

$$\text{Net energy} = \text{Output energy (MJ ha}^{-1}) - \text{Input energy (MJ ha}^{-1}) \tag{6}$$

2.3. *Energy modeling*

2.3.1. *Cobb-Douglas modeling*

The multiple linear regressions model was used to establish the relationship between inputs and yield. In this regard, among the various types of production models, Cobb-Douglas

Table 1 – Energy coefficients of inputs and output for pomegranate production.

Particulars	Unit	Equivalent (MJ $unit^{-1}$)	References
A. Inputs			
1. Human labor	h	1.96	[7]
2. Machinery	h	62.7	[6]
3. Diesel fuel	l	56.31	[16]
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		66.14	[7]
(b) Phosphate (P_2O_5)		12.44	[7]
(c) Potassium (K_2O)		11.15	[7]
5. Biocides	kg		
(a) Herbicides		238	[6]
(b) Insecticides		101.2	[6]
(c) Fungicides		216	[6]
6. Farmyard manure	kg	0.3	[7]
7. Water for irrigation	m^3	1.02	[7]
8. Electricity	kWh	3.6	[16]
B. Output			
1. Pomegranate fruit	kg	1.9	[11]

production model was used due to its simplicity, physical logic consistency and generalization power. This model has been used to determine the energy in crops production in a lot of researches [19–23]. The overall shape of the model is illustrated in Eq. (7) which is transformed into Eq. (9) by calculating side logarithms of Eq. (7) and inserting eight input energy variables considered in Eq. (8).

$$Y = f(x)\exp(u) \tag{7}$$

$$\ln Y_i = \alpha + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad i = 1, 2, \ldots, 83 \tag{8}$$

$$\ln Y_i = \alpha 0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \ldots + \alpha_8 \ln X_8 + e_i \tag{9}$$

where α_0 and e_i are constant coefficient and the error coefficient, respectively. y_i is yield level of the i_{th} farmer, x_{ij} is the vector inputs used in production, $\alpha_1, \alpha_2, \ldots, \alpha_8$ are regression coefficients of energy inputs and x_1, x_2, x_3, x_4, x_5, x_6, x_7 and x_8 are human labor, machinery, diesel fuel, chemical fertilizer, biocides, farmyard manure, water for irrigation and electricity energies, respectively.

To analyze the degree of change in the output regarding to the degree of change in inputs, the return rate to scale was used [10,24,25]. Rate to scale was determined by summing up the regression coefficients obtained for the developed Cobb-Douglas model (Taheri-Rad et al., 2017). Presence of autocorrelation in the developed Cobb-Douglas model was determined by Durbin-Watson test [26].

The regression relationships of different kinds of energy with pomegranate yield were also investigated in Eqs. (10) and (11). In these equations, y_i was the yield of i_{th} unit and β_i were the regression coefficients of direct forms (DE) and indirect forms (IDE) of energy and Y_i were regression coefficients of renewable (RE) and non-renewable (NRE) forms of energies.

$$\ln Y_i = a_0 + \beta_1 \ln DE + \beta_2 \ln IDE + e_i \tag{10}$$

$$\ln Y_i = a_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \tag{11}$$

2.3.2. *Sensitivity analysis*

In this study, marginal physical productivity (MPP) approach was used to sensitivity analysis of energy inputs. In this regard, Eq. (12) was employed to sensitivity analysis of energy inputs for the studied agricultural production system. This model shows that while other production variables are fixed, how much changes happen in yield with one unit increase in each energy input [23,27].

$$MPP_{xj} = \frac{GM(Y)}{GM(X_{ij})} \times \alpha_{ij} \tag{12}$$

where MPP_{xj} is the marginal physical productivity of j_{th} input, α_{ij} denotes the regression coefficient of j_{th} input, $GM(Y)$ is geometric mean of yield and $GM(X_{ij})$ denotes geometric mean of j_{th} input energy per hectare [7,28,29].

2.4. *Economic analysis*

For economic evaluation of pomegranate production in Behshahr city, variable, fixed and total production costs per unit area were calculated. Economic indicators such as total production value, gross return, net return, benefit to cost ratio and economic productivity were calculated according to the Eqs. (13)–(17) [30,31]. Data analysis was performed using statistical software JMP8, and regression equations were established between inputs and yield using the linear regression method.

$$\begin{aligned}\text{Total production value } (\$\ ha^{-1}) &= \text{Pomegranates yield } (kg\ ha^{-1}) \\ &\quad \times \text{Pomegranates price } (\$\ kg^{-1})\end{aligned} \tag{13}$$

$$\begin{aligned}\text{Gross return } (\$\ ha^{-1}) = \text{Total production value } (\$\ ha^{-1}) \\ - \text{Variable production cost } (\$\ ha^{-1})\end{aligned} \tag{14}$$

$$\text{Net return } (\$\text{ ha}^{-1}) = \text{Total production value } (\$\text{ ha}^{-1}) - \text{Total production cost } (\$\text{ ha}^{-1}) \quad (15)$$

$$\text{Benefit to cost ratio} = \frac{\text{Total production value } (\$\text{ ha}^{-1})}{\text{Total production cost } (\$\text{ ha}^{-1})} \quad (16)$$

$$\text{Economic productivity} = \frac{\text{Pomegranates yield (kg ha}^{-1})}{\text{Total production cost } (\$\text{ ha}^{-1})} \quad (17)$$

3. Results and discussion

3.1. Energy results

Pomegranate harvest in this area starts from the end of September and continues until the end of November. The results showed that the average size of pomegranate orchards was 1.8 hectares in Behshahr. The density of pomegranate trees in the area was 335 per hectare and the average age of trees was 18.5 years. About 60.6% of the pomegranate orchards area were located in Sloping areas and 39.4% of the pomegranate orchard area in the lowland areas. It is worth mentioning that fruit harvesting operation is done manually in this city. In Table 2, the amount of used inputs, as well as the proportion of energy content of each input was provided. The results showed that the average production of pomegranate in Behshahr city was 6987.66 kg ha^{-1}, while the average production of the fruit was 10,700 kg ha^{-1} in the country [5]. The average yield of pomegranate production in Turkey were also 35118.67 kg ha^{-1} [11] and 23,350 kg ha^{-1} [3]. The comparison of pomegranate yield in Behshahr with the yield in Turkey and also the average pomegranate production in Iran were demonstrated the relatively low pomegranate yield in Behshahr. Total energy consumption in the pomegranate orchards was calculated 11195.06 MJ ha^{-1}. The amount of this energy for pomegranate in Turkey was reported 40064.87 MJ ha^{-1} [11] and 53764.63 MJ ha^{-1} [3]. The amount of total energy consumption for kiwi and Citrus were reported 30205.2 MJ ha^{-1} [10] and 17112.2 MJ ha^{-1} [8], respectively, in Mazandaran province. This amount was also reported 37536.96 MJ ha^{-1} for peach in Golestan province [6] and 42819.25 MJ ha^{-1} for apple in Tehran province [16]. The comparison between average energy input for the production of pomegranate in Behshahr and other products mentioned before indicated low energy input for pomegranate production in Behshahr. The input energy for pomegranate production in Turkey was 3 to 5 times more than input energy in this area. The reason for low pomegranate productivity in this city can be due to low energy input or non-optimal energy consumption in production. The energy contribution of each input used in the production of pomegranate was shown in Fig. 1. In this study, like many other studies conducted on input energy for the production of agricultural products in Iran, diesel fuel was considered as the most commonly used energy in production. The diesel fuel input with the amount of 93.25 l ha^{-1} which was equivalent to 5128.89 MJ ha^{-1} had the largest share of energy consumption by 45.81% amount among all of the inputs.

For the production of peach in Golestan, diesel fuel input with 175.42 l ha^{-1} and energy consumption of 9877.90 ha^{-1} had the most share of energy consumption with 26.32% [16]. The amount of this energy for the production of pomegranate in Turkey was 1515.87 MJ ha^{-1} and 2.82% [3]. It was 7929.06 MJ ha^{-1} and 19.68% for the production of nectarine in Sari city [9], 1289.01 MJ ha^{-1} and 13.27% for the production of citrus in Mazandaran province [8] and 2304.77 MJ ha^{-1} and 4.47% for the production of banana in Turkey [32]. The amount of diesel fuel consumption for the production of pomegranate in Behshahr was more than diesel fuel consumption for the production of pomegranate and banana in Turkey and citrus in Mazandaran and it was less than diesel fuel consumption for the production of peach in Golestan province and nectarine in Sari. Although, diesel fuel was not used for harvesting, a large amount of diesel fuel was used for transportation

Table 2 – Energy use pattern of pomegranate production.

Particulars	Unit	Quantity per unit area (ha)	Total energy equivalents (MJ ha^{-1})	Percentage of total energy input
A. Inputs				
1. Human labor	h	403.35	790.57	7.06
2. Machinery	h	20.64	1294.08	11.56
3. Diesel fuel	l	91.08	5128.89	45.81
4. Chemical fertilizers	kg			
(a) Nitrogen (N)		30.35	2007.68	17.93
(b) Phosphate (P_2O_5)		28.32	352.27	3.15
(c) Potassium (K_2O)		23.28	267.72	2.39
5. Biocides	kg			
(a) Herbicides		0.18	43.53	0.39
(b) Insecticides		0.60	60.41	0.54
(c) Fungicides		0.48	103.22	0.92
6. Farmyard manure	kg	841.96	252.59	2.26
7. Water for irrigation	m^3	81.16	82.79	0.74
8. Electricity	kWh	225.36	811.31	7.25
Total energy input	MJ		11195.06	100
B. Output				
1. Pomegranate fruit	kg	6987.66	13276.56	

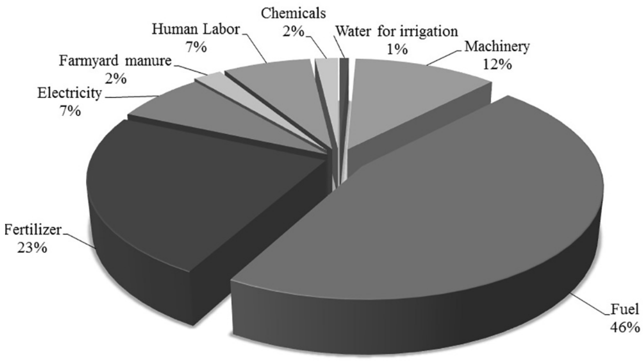

Fig. 1 – The share of energy inputs of pomegranate production.

(43.57% from fuel energy), irrigation (81.24% from fuel energy) and tillage (23.00% from fuel energy) for the production of pomegranate in the area. The reason for the high diesel fuel consumption can be due to using old (worn out) machinery in the area, no-regulated accelerator, and not using the suitable gear by most farmers.

As well as, fertilizers by consuming 81.93 kg ha^{-1} which was equivalent to 2627.67 MJ ha^{-1}, had the second part of the energy used with 23.47% in the production of this fruit. Nitrogen fertilizer with 2007.68 MJ ha^{-1} and 17.93%, was constituted the most energy compared to other fertilizers. This data can be compared with the results obtained from the production of pomegranate in Turkey where the amount of energy consumption for chemical fertilizers was 21621.55 MJ ha^{-1} and 40.22%. Nitrogen fertilizer with 17507.34 MJ ha^{-1} and 32.56% had the largest amount of consumption among chemical fertilizers [3]. In some similar research in Iran, this factor (chemical fertilizers) were the most commonly used factor in production and nitrogen fertilizers were the most commonly used fertilizers among chemical fertilizers [8,33]. The reasons of the increase of chemical fertilizers in the total energy can be not taking samples of the soil to determine the appropriate amount of fertilizer for it and uncontrolled (indiscriminate) use of chemical fertilizers. Machinery input with the consumption of 20.64 h ha^{-1} which was equal to 1294.08 MJ ha^{-1} had the third large share of consumed energy with 11.56% in the production of pomegranate. Subsequently, transportation with the consumption of 55.75% and spraying operation with 13.11% had the most and the least energy consumption in machinery input, respectively. This results can be compared with banana in Turkey in which machinery factor with energy consumption of 10613.24 MJ ha^{-1} and 20.58% was the third highly consumed input and transportation with 53.74% energy consumption had the largest share of energy consumption in machinery [32]. Regarding to the high consumption of this factor in transportation (55.74% of machinery energy) and plowing (17.23% of machinery energy), and despite of not using of this input in harvesting operation, machinery input was known as one of the highly consumed input in production. The cause of high energy consumption in transportation was the long distance between orchards and villages and the high frequency of transportation because of the sloping ground. The reason for low energy consumption in plowing stage was due to low frequency of plowing in the orchards. The average number of plowing were 0.83, 0.58 and 0.35 times per hectare with disk harrow, moldboard, and rotavator, respectively and 7.22% of orchards in this area were located at Sloping had no plowing at all.

Electricity – with only 7.25% usage of the total energy consumption - was in the next stage in terms of energy consumption. The use of this input was 225.36 kWh ha^{-1} and its energy equivalent was also 811.31 MJ ha^{-1}. The amount of this input for the production of peach in Golestan province was reported 5901.17 MJ ha^{-1} and 15.73% [6] and 4352.54 MJ ha^{-1} and 8.10 was also reported for pomegranate in Turkey [3]. In this area, the electricity was only used for irrigation and since water engines were worn out (old) and had little efficiency, a lot of energy wasted. Irrigation operation was also used a large amount of electricity apart from consuming a large amount of diesel fuel.

After electricity, the human labor inputs use with 7.06% was the next in terms of energy consumption. The consumption of this input and its energy were 403.35 h ha^{-1} and 7900.57 MJ ha^{-1}, respectively. Harvesting with 45.28% energy consumption, guarding with 21.58% and shoveling with 8.97% energy consumption had the highest consumption rate in this input. For the production of pomegranate in Turkey, the amount of energy consumption for human labor was reported 2277.46 MJ ha^{-1} and 4.24% and harvesting with 41.27%, was the highest energy consumption in this input [3]. Shoveling and guarding were regarded as the high consumer of this input. Replacing shoveling with machine operations, building walls and fences around the orchard instead of guarding could considerably decrease the energy consumption of this input.

Farmyard manure input with 841.96 kg ha^{-1} and 252.59 MJ ha^{-1} had little share in the production of pomegranate in the area with 2.26%. Among farmyard manure input, cow manure (with 44.12% of farmyard manure energy) and chicken manure (with 29.37% of farmyard manure energy) were the highest consumption of farmyard manure. This result can be compared with the results obtained from the production of peach in Golestan province with 3265.80 MJ ha^{-1} [6], pomegranate in Turkey with 300.00 MJ ha^{-1} [3] and pear in Tehran province with 2477.26 MJ ha^{-1} [7]. In all these studies, farmyard manure energy had been one of the least consumed input. The comparison of results showed that the amount of farmyard manure use in Behshahr was less than other areas because of this input was not used in 36.14% of this city's orchards at all.

Two inputs including biocides and water for irrigation had the lowest energy consumption. Chemical pesticides input with the consumption of 1.26 kg ha^{-1} and 201.16 MJ ha^{-1} had a little share with 1.85% in the production of pomegranate. Among other pesticides, fungicides with 103.22 MJ ha^{-1} consumption compared with other pesticides had the most energy consumption. In some various research in Iran, energy consumption of fungicides was also the highest among pesticides [3,6,9,34]. Water for irrigation energy with the share of 81.16 m^3 ha^{-1} and 82.79 MJ ha^{-1} had also the least energy consumption among production inputs. The results of energy consumption in irrigation can be compared with the production of peach in Golestan province with

1105.52 MJ ha^{-1} [6] and nectarine in Sari with 3749.33 MJ ha^{-1} [9]. In all these research, water for irrigation was considered a less consumed input. The comparison also demonstrated that water consumption for irrigation in Behshahr was less than other areas. The average number of irrigation was 1.02 per hectare, and only 21.7% of orchards were irrigated in the area.

3.2. Energy indices

In Table 3, energy indices for the production of pomegranate in Behshahr are presented. By using energy indices, it is possible to compare systems and organization for production in different areas or different products in the same area [6]. Energy ratio for the production of this fruit was 1.18 which showed that about 1.18 energy units was produced with one unit energy consumption. The amount of this index was 1.87 [5] and 1.04 [3] for the production of pomegranate in Turkey. This amount was also 1.54 for kiwi [10] and 1.71 for citrus [8] in Mazandaran. In this study, the index of energy productivity was reported 0.62 kg MJ^{-1}. It showed that 0.62 kg output was produced for every MJ energy consumption. The higher amount of this ratio showed the higher productivity of energy consumption. The amount of this index for the production of pomegranate in Turkey was calculated as 43.0 kg MJ^{-1} [3] and it was calculated 0.63 kg MJ^{-1} and 0.27 kg MJ^{-1} for apple in Turkey [34] and for pear in Tehran, respectively [7]. Specific energy index in this research was calculated as 1.60 MJ ha^{-1} which showed that 1.60 MJ energy had been consumed for the production of one kilogram pomegranate. The amount of this index was 2.30 MJ kg^{-1} for pomegranate in Turkey [3], 3.41 MJ kg^{-1} for peach in Golestan province [6], 3.72 MJ kg^{-1} for pear in Tehran province [7] and 2.06, 2.05 and 1.59 MJ kg^{-1} for apple in Tehran, Isfahan and Turkey, respectively. Net energy index of 2081.50 MJ ha^{-1} was obtained for this research which showed that output energy had been more than input energy. The amount of this index for pomegranate in Turkey was 2275.37 MJ ha^{-1} [3], for citrus in Mazandaran was 12251.40 MJ ha^{-1} [8] and for pear in Tehran province was also 84466.30 MJ ha^{-1} [7]. Since there had been no comprehensive research on energy analysis of pomegranate in Iran and different parts of the world, one can not exactly compare energy indices for this product in different areas.

Fig. 2 shows the amounts of direct, indirect, renewable and non-renewable energies consumption for pomegranate production. The shares of direct and indirect energies in production were calculated 6813.56 MJ ha^{-1} and 4381.50 MJ ha^{-1} which constituted 60.86% and 39.14% of input energies, respectively. Renewable energies with 1125.96 MJ ha^{-1} consumption and 10.06% of the total input energies were less than non-renewable energies consumption with 10069.10 MJ ha^{-1} and 89.94%. For pomegranate in Turkey, the share of direct and indirect energies was calculated 15.15% and 84.85% and renewable energies 9.8% and 90.2%, respectively [3]. It is clear that the share of non-renewable energies consumption for the production of pomegranate in Iran is high. Non-renewable energy inputs consumption in agricultural sector in Iran can cause several environmental impacts such global warming, acidification, eutrophication, depletion of resources [35–37]. However, Iran has a great potential of renewable energy sources such as solar, biomass, wind [38].

3.3. Energy modeling results

Table 4 displays the use of Cobb-Douglas model to determine the effect of the energy inputs on the pomegranate yield in Behshahr, Iran. The amount of R^2 for the Eq. (9) was equal to 0.71, which demonstrated that about 71% of changes in yield were predictable by the independent variable. For the data used in this model, the autocorrelation was investigated using Durbin-Watson test. The amount of correlation was 1.72 which means that among the data on 5% there was no autocorrelation. The effect of energy inputs including human labor, biocides, chemical fertilizers, farmyard manure, water for irrigation and electricity were positive on the yield; however, the impact of energy inputs including diesel fuel and agricultural machinery were negative on the pomegranate yield. In the analysis of production energy of peach in Golestan province of Iran, the effects of diesel fuel input, human labor, electricity, chemical fertilizers and farmyard manure were positive and the effects of water for irrigation, biocides and machinery inputs were negative [6]. The energy of chemical fertilizers with 0.54 had the highest regression coefficient among other factors influencing the yield. It means that one percent increase in the use of chemical fertilizers in the

Table 3 – Energy indices of pomegranate production.

Item	Unit	Quantity
Energy efficiency	–	1.18
Energy productivity	kg MJ^{-1}	0.62
Specific energy	MJ kg^{-1}	1.60
Net energy	MJ ha^{-1}	2081.50
Direct energy[a]	MJ ha^{-1}	6813.56
Indirect energy[b]	MJ ha^{-1}	4381.50
Renewable energy[c]	MJ ha^{-1}	1125.96
Non- renewable energy[d]	MJ ha^{-1}	10069.10
Total energy input	MJ ha^{-1}	11195.06
Total energy output	MJ ha^{-1}	13276.56

[a] Includes electricity, diesel fuel, human labor, water for irrigation.
[b] Includes chemicals, farmyard manure, chemical fertilizer, agriculture machinery.
[c] Includes water for irrigation, human labor, farmyard manure.
[d] Includes agriculture machinery, electricity, diesel fuel, chemical fertilizer, chemicals.

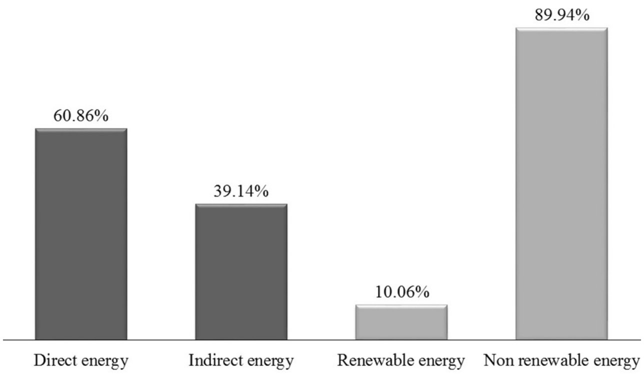

Fig. 2 – The shares of direct, indirect, renewable and non-renewable energy for pomegranate production.

orchard of this area will increase the yield by 0.54%. In the analysis of the production energy of apple and peach, the regression coefficients of this input were 0.01 and 0.07, respectively [6,16]. The second most effective input after chemical fertilizers was diesel fuel with −0.34, but its effect was negative. It implies that with 0.01 decrease in diesel fuel consumption in orchards of this area, the yield would increase by 34.0%. The return to scale ratio showed the degree of change in the yield of products in return for changes in all inputs which was 0.19 for this equation. It means that with one percent increase in input energies of all inputs, the yield would increase by 0.19%.

The results of sensitivity analysis showed that with one MJ increase in input energies of electricity, human labor, biocides, animal manure, chemical fertilizers and water for irrigation, the yield would increase as much as 0.06, 0.10, 0.67, 1.30, 1.42 and 3.12 kg, respectively. And with one MJ increase in energy inputs of diesel fuel and machinery, yield would decrease 0.47, 0.67 kg, respectively, in a certain extent. Royan et al. [6] studied the energy use pattern of peach production. The results of sensitivity analysis showed that increasing one MJ of energy inputs of human labor, machinery, diesel fuel, chemical fertilizers, biocides, farmyard manure, irrigation water and electricity changed the yield by 11.31, -2.8, 1.33, 0.29, −0.003, 0.54, and 0.14 kg, respectively. In research on apple production, the amounts of MPP for inputs, human labor, water for irrigation, biocides, electricity, chemical fertilizers, farmyard manure, diesel fuel and machinery were reported 1.30, 2.43, 0.71, 0.32, 0.06, 0.62, 0.40 and 0.53, respectively [16].

The results of using Cobb-Douglas model to determine the relationship between different input energies and the production of pomegranate in Behshahr are illustrated in Table 5. The obtained amount of R^2 for Eq. (10) which relates to direct and indirect energies was 0.66. The results showed that the effect of both of these energies on yield had been positive while indirect energies had more effect than direct energies. The rate of return to scale was also calculated for this equation as 1.08. The results of various research conducted in Iran also showed that the effects of both direct and indirect energies were positive, and indirect energies had more impact on yield [6,7,10,29]. The amount of R^2, related to the renewable and non-renewable energies was 0.63 in Eq. (11). The effects of both energies on the production of pomegranate were positive, and the effect of renewable energies on yield was more. This result can be compared with ones obtained in the study done on the production of pear in Tehran in which the effects of both energies were positive and renewable energies had more effect yield [7].

3.4. *Economic analysis of pomegranate production*

In this section, some economical indices in the production of pomegranate in Behshahr were investigated. As illustrated in Table 6, the variable, fixed and total costs of pomegranate production in Behshahr were calculated 548.25, 153.51 and 701.76 \$ ha^{-1}, respectively. In variable costs, human labor inputs with 64.06% had the highest costs related to the production, in which harvesting operations by consuming 182.6 h of human labor per hectare and 48.76% share of human labor costs had the largest cost of the input. For the production of pomegranate in Turkey, the human labor input with the consumption of 26.7% of total production costs was the highest production cost [3]. Machinery input was the second expensive input with the share of 19.77% of costs, in which the transportation had the largest share in machinery costs with

Table 4 – Sensitivity analysis of energy inputs of pomegranates.

Independent	Coefficient	(t-ratio)	P-Value	MPP
Model : $\ln Y_i = a_0 + \alpha_1 \ln x_1 + \alpha_2 \ln x_2 + \alpha_3 \ln x_3 + \alpha_4 \ln x_4 + \alpha_5 \ln x_5 + \alpha_6 \ln x_6 + \alpha_7 \ln x_7 + \alpha_8 \ln x_8 + e_i$				
Human labor	0.011	0.21	.833	0.097
Machinery	−0.12	−1.69	.095	−0.675
Diesel fuel	−0.345	−1.26	.213	−0.470
Biocides	0.020	1.67	.099	0.675
Chemical Fertilizers	0.536	1.99[b]	.048	1.420
Farmyard manure	0.047	4.12[a]	.001	1.300
Water for irrigation	0.037	1.54	.127	3.123
Electricity	0.007	0.59	.556	0.060
R^2	0.71			
Durbin-Watson	1.72			
Return to scale	0.188			

[a] Indicates significance at 1% probability level.
[b] Indicates significance at 5% probability level.

Table 5 – The effects of different forms of energy on the yield of pomegranate.

Independents	Coefficient	t-ratio	MPP
$\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i$			
Direct energy	0.24	7.18[a]	0.246
Indirect energy	0.84	4.39[a]	1.340
R^2	0.66		
Durbin Watson	1.58		
Return to scale	1.08		
$\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$			
Renewable energy	0.30	2.77[a]	1.862
Non-renewable energy	0.20	5.88[a]	0.139
R^2	0.63		
Durbin Watson	1.64		
Return to scale	0.50		

[a] Indicates significance at 1% probability level.
[b] Indicates significance at 5% probability level.

the share of 44.04%. The value of total production or the gross return of production was estimated as 3960.92 $ ha^{-1}, and the total cost of production was calculated as 701.76 $ ha^{-1}. Concerning economical indices, the wet and gross return were also estimated as 3205.15 and 3358.66 ha^{-1}, respectively. The average benefit to cost ratio that was calculated about 5.57 for pomegranate cultivation in Behshahr city that showed pomegranate production in the region has been profitable. The amount of this index was 1.55 for pomegranate in Turkey [3], 3.32 for the production of plum in Tehran [33] and 16.74 for nectarine in the Sari city [9]. The amount of productivity was calculated as 9.96 kg $$^{-1}$. It means that 9.96 kg product was produced for each dollar cost in the production of pomegranate. These results can be compared with the results obtained from the production of pear in Iran province in which the amount of this index was 3.89 kg $$^{-1}$ [7].

3.5. *Economic modeling*

The regression coefficients of the inputs cost and the amount of return rate to scale are illustrated in Table 7. The amount of Durbin-Watson statistic was calculated as 1.58 which showed that there was not autocorrelation on the level of 5% amongst the data. Amongst obtained regression coefficients, the cost of diesel fuel (0.173), machinery (-0.032) and farmyard manure (0.031) had the largest coefficients which showed that these inputs had the most effect on income. It also showed that the effects of the costs of human labor input, machinery and electricity on income were negative and cost coefficients of farmyard manure and biocides had a meaningful effect on income. The amount of R^2 was calculated 0.64 which showed that 64% of changes in the dependent variable (income) can be defined by independent variables. The total of

Table 6 – Economic analysis of pomegranate production.

Item	Unit	Average	Standard deviation	Percentage (%)
Human labor	$ ha^{-1}	351.22	222.69	64.06
Agriculture machinery	$ ha^{-1}	108.41	105.83	19.77
Chemical fertilizers	$ ha^{-1}	56.61	104.03	10.33
Farmyard manure	$ ha^{-1}	13.72	22.77	2.50
Biocides	$ ha^{-1}	10.96	22.42	2.00
Diesel fuel	$ ha^{-1}	4.67	5.36	0.85
Water for irrigation	$ ha^{-1}	2.00	5.58	0.37
Electricity	$ ha^{-1}	0.66	3.02	0.12
Variable cost of production	$ ha^{-1}	548.25	396.34	–
Fixed cost of production	$ ha^{-1}	153.51	110.97	
Total cost of production	$ ha^{-1}	701.76	507.31	
Sale price	$ kg^{-1}	0.56	0.15	
Gross value of production	$ ha^{-1}	3960.92	2179.61	
Economic indicators				
Benefit to cost ratio		5.57		
Economic productivity	kg $$^{-1}$	9.96		
Gross return	$ ha^{-1}	3358.66		
Net return	$ ha^{-1}	3205.15		

Table 7 – Economical modeling of pomegranates production using Cobb-Douglas.

Item	Coefficient	t-ratio	P-Value
Human labor	−0.004	−0.04	.970
Machinery	−0.032	−0.39	.694
Diesel fuel	0.173	1.89	.062
Biocides	0.026	2.62[b]	.011
Chemical Fertilizers	0.011	1.32	.191
Farmyard manure	0.031	3.39[a]	.001
Water for irrigation	0.002	0.2	.843
Electricity	−0.011	−0.75	.475
R^2	0.64		
DurbinWatson	1.58		
Return to scale	0.198		

[a] Indicates significance at 1% probability level.
[b] Indicates significance at 5% probability level.

Cobb-Douglas model coefficients showed the rate of return to scale. For this equation, this amount was 0.2 which showed that there was an increasing rate of return to scale meaning that increase in the dimension of agricultural activities, was decreased the costs. The amount of this index for the production of peach in Golestan province was 1.55 [6].

4. Conclusion

In this study, the process of energy consumption and costs of the production of pomegranate in Behshahr city was analyzed and investigated. Average fruit production, total consumed energy and total output energy of pomegranate production in Behshahr city were obtained 6987.66 kg ha^{-1}, 11195.06 MJ ha^{-1} and 13276.56 MJ ha^{-1}, respectively. The fruit yield was low in this city that can be due to the low amount of input energy or the amount of energy used in the production. Another reason was because the energy was not optimal. The diesel fuel input was the mostly used input in the production due to the exhaustion of the machines in the area, failure to use the proper gear by most farmers, the long road from the village to the orchards, and how frequent transportation to and from the orchards due to steep roads. Pomegranate production and energy efficiency in this region was low, and improving strategies should be taken to increase crop yield and/or save energy input. The effect of human labor, biocides, farmyard manure, water for irrigation and electricity inputs on yield was positive and effect of diesel fuel inputs, agricultural machinery on the yield of pomegranate was negative. The results of the sensitivity analysis of input energy showed that one MJ increase in water for irrigation and chemical fertilizers input energies led to 3.12 kg and 1.42 kg increase in their yields, respectively. In variable costs, human labor and machinery inputs had the most cost of the production as much as 64.06% and 19.77%, respectively. Harvesting operation in human labor input and transportation in machinery input had the most cost in these two inputs. The average of benefit to cost ratio for the production of pomegranate in Behshahr was 5.75 which showed that the production of pomegranate in the area was profitable.

Acknowledgment

The authors gratefully acknowledge the financial support provided by Ferdowsi University of Mashhad. Gratitude also goes to Dr. Amin Nikkhah and Dr. Alireza Taheri-Rad for their guidance throughout some parts of this research.

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