Application of a non-parametric method to analyze energy consumption for orange production

Peyman Qasemi-Kordkheili*, Mohammad Amin Asoodar, Navab Kazemi

(*Department of Agricultural Machinery Engineering and Mechanization, Khouzestan Ramin Agriculture and Natural Resources University, Mollasani, Khouzestan, Iran*)

Abstract: Due to good climate condition and large cultivation area in Mazandaran province of Iran, orchard commodities products, especially orange production is widely improved in this region. In this study, Data Envelopment Analysis (DEA) technique was used to analyze the efficiency of farmers, discriminate efficient orchards from inefficient ones and to identify wasteful uses of energy for orange producers in Sari region. Data were collected using face-to-face surveys from 86 orange orchardists and included the human power, machinery, diesel fuel, chemicals, fertilizer, farmyard manure, water for irrigation and electricity input sources used per hectare of orange production. The data was organized and analyzed by DEA Techniques. The results revealed that the total input and output energy were 54.2 and 59.2 GJ/ha, respectively. Diesel fuel, fertilizer and water for irrigation energies had the highest energy values per hectare respectively. Pure technical and scale efficiencies were calculated using CCR (Charnes–Cooper–Rhodes) and BCC (Banker-Charnes-Cooper) models. The technical, pure technical and scale efficiencies were calculated as 0.92, 0.96 and 0.97, respectively. The highest contribution to the total saving energy was provided by diesel fuel followed by fertilizer and water for irrigation energy input.

Keywords: technical efficiency, energy saving, data envelopment Analysis, orange production, Sari

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1 Introduction

The orange (specifically, the sweet orange) is the fruit of citrus trees belonging to the *Rutaceae* family. Annual production and cultivation area placed Iran in the top ten orange-producing countries of the world (Singh et al., 2002). Based on FAO statistics, about 7.75 million tons of citrus are consumed worldwide each year. One of the most widely favored fruits in Iran is citrus and rose sharply in recent years. In 2008, about 5500 ha of lands were allocated to citrus farming and about 80,000 tons oranges were produced in Iran (Anonymous, 2010). Citrus is the most important horticultural crop in Mazandaran province with about 40% of annual production in Iran (Anonymous, 2005).

Energy efficiency improvement is a key indicator for sustainable energy management; for enhancing the energy efficiency it must be attempted to increase the production yield or to conserve the energy input without affecting the yield level (Singh et al., 2004). The need to increase food production has resulted in the increased consumption of energy and natural resources because farmers have little knowledge of or few incentives to use more energy efficient methods (Esengun et al., 2007). Several investigations had been done on energy use for agricultural commodities such as: Strapatsa et al. (2006) investigated energy flow for integrated apple production in Greece; La Rosa et al. (2008) studied oranges production in Italy; Qasemi kordkheili et al. (2013a) and Tabatabaie et al. (2013) investigated energy input-yield relationships and

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* **Corresponding author: Peyman Qasemi-Kordkheili,** Department of Agricultural Machinery Engineering and Mechanization, Khouzestan Ramin Agriculture and Natural Resources University, Mollasani, Khouzestan, Iran. Tel.: (+98) 9351757884, Fax: +98 6123223922. Email: p.qasemi88@gmail.com.

cost analysis for nectarine and pear production in Mzandaran province of Iran, respectively.

There are several parametric and non-parametric techniques to measure productive efficiency. Data Envelopment Analysis (DEA) is a non-parametric technique which is used extensively in many settings for measuring the efficiency and benchmarking of decision making units (DMUs). The main advantage of non-parametric method of DEA compared to parametric ones is that it assumes neither a preconceived functional relationship imposed between inputs and outputs, nor the prior information about weights of inputs and outputs in contrast to parametric statistical approaches (Mohammadi et al., 2011). DEA allows the decision makers to simultaneously consider multiple inputs and outputs, where efficiency of each DMU is compared to that of an ideal operating unit rather than to the average performance (Mousavi-Avval et al., 2011). Mohammadi et al. (2011) and Mousavi-Avval et al. (2011) applied DEA approach to determine the efficiencies of kiwifruit and apple orchards in Mazandaran province of Iran, respectively. Also, Taki et al. (2012) employed a non-parametric method of DEA to estimate the energy efficiencies of cucumber producers in Esfahan province of Iran. According to the literature it was determined that there has been no previous study to discuss about the technical, pure technical and scale efficiency of orange producers in Iran. Therefore, the present study was undertaken to discriminate efficient orchards from inefficient ones and to identify the wasteful uses of energy by DEA method, in order to optimize the inputs on orange production in Sari regions of Iran.

2 Materials and methods

In this study, orange growers of Sari region were surveyed. Sari region is located in the northern part of Iran within 35° 58 and 36° 50 north latitude and 52° 56 and 53° 59 east longitude. Data were collected using the personal interview method in a specially designed schedule during the 2011/2012 production year. The size of each sample was determined using Equation (1) (Kizilaslan, 2009).

$$n = N(S\times T)^2/(N-1)d^2 + (S\times T)^2 \qquad (1)$$

where, n is the required sample size; N is the number of holdings in the target population; S is the standard deviation; T is the t-value at a 95% confidence limit (1.96); and d is the acceptable error (permissible error 5%). The calculated sample size in this study was determined to be 86 orange farms. Consequently, based on this number, 86 orange farmers in Sari region were randomly selected. In this study, gathered data included the quantity of human power, machinery, diesel fuel, chemicals, fertilizers, farmyard manure, water for irrigation and electricity input sources used per hectare and orange production yield was used to calculate output energy. To calculate the embodied energy in agricultural machinery, it was assumed that the energy consumed for the production of the tractors and agricultural machinery is depreciated during their economic life time (Mousavi-Avval et al., 2011b). Therefore, the machinery energy input was calculated using Equation (2) (Gezer et al., 2003).

$$ME = G \times M_P \times t/T \qquad (2)$$

where, ME is the machinery energy per unit area (MJ/ha); G is the machine mass (kg); M_p is the production energy of machine (MJ/kg); t is the time that machine used per unit area (h/ha) and T is the economic life time of machine (h) (Mousavi-Avval et al., 2011b). The data were calculated for one hectare was converted into energy units and expressed in MJ/ha. The energy equivalents of all eight input sources were used to calculate the input amounts and are given in Table 1.

Energy ratio = Energy Output (MJ/ha)/ Energy Input (MJ/ha) (3)

Energy productivity = Orange yield (Kg/ha)/ Energy input (MJ/ha) (4)

Specific energy = Energy input (MJ/ha)/ Orange yield (MJ/ha) (5)

Net energy = Output energy (MJ/ha) – Input energy (MJ/ha) (6)

Energy efficiency is one of the main energy indices used to determine overall productivity in the agricultural sector. In the other words, this ratio, which is calculated as the ratio between input fossil fuel energy and output food energy, is one commonly used to express the effectiveness of crop production in developed countries (Mousavi-Avval et al., 2011a). Energy requirements in agriculture can be divided into two groups: direct and indirect energy. Direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, interculture, threshing, harvesting and transportation of agricultural inputs and farm products (Singh, 2000). Indirect energy is the energy spent outside the farm for the manufacture of many input sources such as fertilizers and machinery (Tabatabaie et al., 2013) and includes the energy embodied in fertilizers, farmyard manure, chemicals and machinery while direct energy consists of human labor, electricity, diesel fuel, and water for irrigation. Non-renewable energy consists of diesel, chemicals, electricity, fertilizers and machinery energies while renewable energy includes human labor, farmyard manure and water energies (Royan et al., 2012).

Table 1 Energy equivalent coefficients of inputs and output

Item	Units	Energy equivalent (MJ unit^{-1})	References
		Input	
1.Diesel fuel	L	47.8	(Rahbari et al., 2013)
2.Electricity	kWh	11.93	(Mohammadi and Omid, 2010)
3.Human power	H	1.96	(Qasemi-Kordkheili et al., 2013b)
4.Water for irrigation	m^3	1.02	(Qasemi-Kordkheili et al., 2013a)
5.Machinery	kg	62.7	(Namdari et al., 2011)
6.Fertilizer	kg		
Nitrogen		66.44	(Mohammadi and Omid, 2010)
Phosphate (P_2O_5)		12.44	(Mohammadi and Omid, 2010)
Potassium (K_2O)		11.15	(Mohammadi and Omid, 2010)
Sulfur (S)		1.2	(Mohammadi et al., 2010)
7.Farmyard manure		0.3	(Qasemi-Kordkheili et al., 2013a)
8.Chemicals	kg		
Herbicides		238	(Rafiee et al., 2010)
Pesticides		199	(Namdari et al., 2011)
Fungicide		92	(Ozkan et al., 2004)
		Output	
1.Orange	kg	1.9	(Ozkan et al., 2004)

2.1 Data envelopment analysis

DEA is a data-oriented technique used for estimation of resource use efficiency and ranking production units on the basis of their performances. Production units are termed as DMUs in DEA terminology. The DEA model has been described in detail by several authors (Banker et al., 1984). To evaluate the technical, pure technical and scale efficiencies of individual farmers, DEA were used. In this study input variables were defined as human power, machinery, chemicals, water for irrigation, electricity, fertilizers, farmyard manure and diesel fuel, while, the orange yield was the single output variable. In DEA, an inefficient DMU can be made efficient either by reducing the input levels while holding the outputs constant (input oriented); or symmetrically, by increasing the output levels while holding the inputs constant (output oriented) (Mousavi-Avval et al., 2010). The choice between input and output orientation depends on the unique characteristics of the set of DMUs under study. In this study the input oriented approach was deemed to be more appropriate because there is only one output while multiple inputs are used; also as a recommendation, input conservation for given outputs seems to be a more reasonable logic (Galanopoulos et al., 2006).

2.2 Technical efficiency

Technical efficiency (TE) is basically a measure by which DMUs are evaluated for their performance relative to the performance of other DMUs in consideration; it is also called global efficiency. The technical efficiency can be defined as follows (Equation (7)) (Cooper et al., 2004)

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots + v_m x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_s x_{sj}} \qquad (7)$$

where, u_r is the weight (energy coefficient) given to output n; y_r is the amount of output n; v_s is the weight (energy coefficient) given to input n; x_s is the amount of input n; r is number of outputs (r = 1, 2, ..., n); s is number of inputs (s = 1, 2, ..., m) and j represents jth of DMUs (j = 1, 2, . . ., k). To solve Equation (7), Linear Program (LP) was used, which was developed by Charnes et al. (1987):

$$\text{Maximize } \theta = \sum_{r=1}^{n} u_r y_{ri} \qquad (8)$$

$$\text{Subjected to } \sum_{r=1}^{n} u_r y_{ri} - \sum_{s=1}^{m} v_s x_{sj} \leq 0 \qquad (9)$$

$$\sum_{s=1}^{m} v_s x_{sj} = 1 \qquad (10)$$

$$u_r \geq 0,\ v_s \geq 0, \text{ and } (iandj = 1,\ 2,\ 3,\ \ldots,\ k) \qquad (11)$$

where, θ is the technical efficiency and i represent ith DMU, it is fixed in Equations (8) and (9) while j increases in Equation (9). The above model is a linear programming model and is popularly known as the CCR (Charnes–Cooper–Rhodes) DEA model which assumes that there is no significant relationship between the scale of operations and efficiency (AvkIran, 2001). So the large producers are just as efficient as small ones when converting inputs to output.

2.3 Pure technical efficiency

Pure technical efficiency (PTE) is another model in DEA that was introduced by Banker et al. (1984). This model is called BCC (Banker-Charnes-Cooper) and calculates the technical efficiency of DMUs under variable return to scale conditions. Pure technical efficiency can separate both technical and scale efficiencies. The main advantage of this model is that scale inefficient farms are only compared to efficient farms of a similar size (Bames, 2006). It can be expressed by Dual Linear Program (DLP) as follows (Mousavi-Avval et al., 2010):

$$\text{Maximize } z = uy_i - u_i \qquad (12)$$

$$\text{Subjected to } vx_i = 1 \qquad (13)$$

$$-vX + uY - u_0 e \leq 0 \qquad (14)$$

$$v \geq 0,\ u \geq 0 \text{ and } u_0 \text{ free in sing} \qquad (15)$$

where, z and u_0 are scalar and free in sign; u and v are output and input weight matrixes, and Y and X are corresponding output and input matrixes, respectively. The letters x_i and y_i refer to the input and output of ith DMU.

2.4 Scale efficiency

Scale efficiency is the potential productivity gain from achieving optimal size of a DMU. It can be calculated by the relationship between technical and pure technical efficiencies as Equation (16) (Cooper et al., 2004).

$$\text{Scale Efficiency} = \text{Technical efficiency} / \text{Pure technical efficiency} \qquad (16)$$

Additionally, Scale efficiency shows the effect of DMU size on efficiency of system. Simply, it indicates that some part of inefficiency refers to inappropriate size of DMU, and if DMU moves toward the best size the overall efficiency (technical) can be improved at the same level of technologies (inputs) (Nassiri et al., 2009). If a DMU is fully efficient in both the technical and pure technical efficiency scores, it is operating at the most productive scale size. If a DMU has the full pure technical efficiency score, but a low technical efficiency score, then it is locally efficient but not globally efficient due to its scale size. Thus, it is reasonable to characterize the scale efficiency of a DMU by the ratio of the two scores (Sarica and Or, 2007). In the analysis of efficient and inefficient DMUs the Energy saving target ratio (ESTR) index can be used which represents the inefficiency level for each DMUs with respect to energy use. The formula is as follows (Hu and Kao, 2007):

$$\text{ESTR}_j = (\text{Energy saving target})_j / (\text{Actual energy input}) \qquad (17)$$

where, Energy saving target is the total reducing amount of input that could be saved without decreasing output level and j represents jth DMU. The minimal value of energy saving target is zero, so the value of ESTR will be between zero and unity. A zero ESTR value indicates the DMU on the frontier such as efficient ones; on the other hand for inefficient DMUs, the value of ESTR is larger than zero, which means that energy could be saved. A higher ESTR value implies higher energy inefficiency and a higher energy saving amount (Hu and Kao, 2007).

3 Results and discussion

3.1 Analysis of energy input and output in orange production

Orange trees during the growing period need subtropical climate and this condition is provided in sari region. In the present study, 86 orchards growers were carried out. Data were collected in 2012-2013 production year. The physical input sources and their energy equivalents used in the production of orange are presented in Table 2.

From the table above, the total amount of energy input and output are 54,284.8 and 59,223.4 MJ/ha, respectively. It is clear that the average amount of orange yield in this region was 31,170.2 kg/ha. In this study the average amount of diesel fuel, water for irrigation and electrical energy were 281.9 l, 11,835.5 m^3 and 363.9 kWh per hectare, respectively. The total machinery energy input for orange production was 3,482.35 MJ/ha. The average annual rainfall in this region is enough but the large amount of irrigation water usage in this area is the result of

Table 2 Energy input sources, output and their energy equivalents for orange production

Input	Quantity per unit area (Unit/ha)	Total energy equivalent (MJ/ha)
1.Diesel fuel (l)	281.9	13475.3
2.Electricity (kWh)	363.9	4352.5
3.Human power (h)	1342.3	2631.3
4.Water for irrigation (m^3)	11835.5	12072.3
5.Machinery (kg)	4664.1	974.8
6.Fertilizers (kg)		12418.4
Nitrogen	91.5	6079.2
Phosphate (P_2O_5)	326.8	4065.3
Potassium (K_2O)	200.4	2234.4
Sulphur (S)	33	39.6
7.Farmyard manure	15891.1	4768.8
8.Chemicals (kg)		3590
Herbicides	8.3	1990
Pesticides	3.99	795
Fungicide	8.75	805
Total energy input		54284.8
Total energy output	31170.2	59223.4

irrigating on average eight to ten times during each production year. Many famers use diesel powered pumps to irrigate orchards but the remaining farmers use electrical motor pumps with the result that electricity is consumed only for irrigation purposes. Drop and flood irrigating were the two irrigating system used. Fifty-four orchards were irrigated with a flooding system that caused water wastage, while the remaining orchards were equipped with a drop irrigation system. Drop irrigating system has high fixed costs. In calculation of machinery energy, 50 h usage of machines in average per ha and economic life were considered, so the total machinery energy input for orange production was 947 MJ/ha among all orchards, tractors were widely used in all operations. In many operations such as irrigation, tractors are only used to transport water pump motors and pipes so it is a cause of energy wastage and inefficiency. Generally, machinery power was primarily used in spraying operations. The low amount of machinery usage shows that in all operations human power was involved, mainly during the harvesting stage. Additionally, the large amount of diesel fuel used can be explained as the use of depreciated tractors and inefficient motor pumps. In total, 651.7 kg of fertilizers, 15,891.1 tons of farmyard manure and 21.04 kg of chemical agents per ha and also 1,342.3 hr of human power for the production of oranges in Mazandaran province were used. Orange trees are subject to a great number of fungi and pests affecting the roots, the trunk and branches, the foliage and the fruits so timely spraying is necessary. Qasemi Kordkheili et al. (2013a) in their study on nectarine production in Iran, indicated that the total energy consumption was 40,275.24 MJ/ha and among all inputs involved, fertilizer (36.93%) and diesel fuel (19.68%) had the highest energy values per ha. In similar research in the Mazandaran province of Iran, Namdari et al. (2011) found that the total energy used in various farm operations during orange production was 62,375.1 MJ/ha. The highest energy input was provided by diesel fuel followed by chemical fertilizer. Additionally, Ozkan et al. (2004) found similar results for orange, mandarin and lemon productions in Turkey. Also, Mohammadshirazi et al. (2012) found that the total energy requirement for the production of tangerine crops in the Mazandaran province of Iran was about 62,260 MJ/ha and chemical fertilizers had the highest energy consumption. The improvements of energy indices for orange production are presented in Table 3.

Table 3 Energy input-output in orange production

Item	Unit	Value
Energy efficiency	-	1.09
Energy productivity	kg/MJ	0.57
Specific energy	MJ/kg	1.74
Net energy	MJ/ha	4938.5
Direct energy [1]	MJ/ha	32531.5
Indirect energy[2]	MJ/ha	21735.2
Renewable energy[3]	MJ/ha	19472.4
Non- renewable energy[4]	MJ/ha	34812.3
Total energy input	MJ/ha	54284.8
Total energy output	MJ/ha	59223.4

Note: 1. Includes human labor, diesel fuel, water for irrigation, electricity;
2. Includes chemical fertilizers, farmyard manure, chemicals agents, machinery;
3. Includes human labor, farmyard manure, water for irrigation;
4. Includes diesel fuel, electricity, chemicals, chemical fertilizers, machinery.

The overall energy ratio (Energy use efficiency) was calculated as 1.09. Energy productivity was calculated as 0.57 kg/MJ meaning that for every 1 MJ of energy consumed farmers can produce 0.57 kg of orange fruit. Ozkan et al. (2004) in Turkey calculated the energy ratio as 1.25 for orange production. In similar research, Namdari et al. (2010) and Qasemi-Kordkheili et al.

(2013a) reported that the energy ratio and the energy productivity of orchards for orange and nectarine production was 0.99, 0.52 kg/MJ and 1.36, 0.77 kg/MJ in the Mazandaran province of Iran, respectively. Also, Specific energy and net energy were measured as 1.74 MJ/kg and 4,938.5 MJ/ha, respectively. The distribution of energy consumption from direct, indirect, renewable and non-renewable energy resources was also investigated. The results revealed that total energy input was 54,284.8/MJ ha, with 32,531.5 and 2,1735.2 MJ/ha in direct and indirect, and 19,472.4 and 34,812.3 MJ/ha in renewable and non-renewable energy forms, respectively. This amount is lower than other measured amounts of non-renewable energy for other crops such as 86% of total energy for pear production in Iran (Tabatabaie et al., 2013), and 73.36% of total energy for kiwifruit production in Iran (Mohammadi et al., 2011). The distribution of total energy inputs as direct, indirect, renewable and non-renewable energy forms is given in Figure 1.

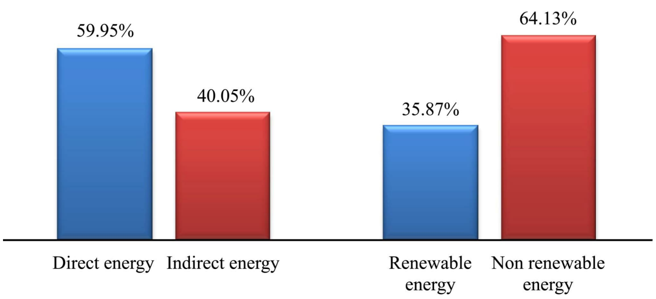

Figure 1 The share of total energy inputs as direct, indirect, renewable and non-renewable energy forms

3.2 Efficiency estimation of orchards

The results of BCC and CCR models of DEA are presented in Figure 2. From the total of 86 orchards considered in this study, 26 orchards had the technical efficiency and 41 orchards had the pure technical efficiency score of 1. It can be concluded that from total of 86 selected orchard 41 farmers had the best practice management. Consequently, the average of pure technical efficiency and technical efficiency were 0.96 and 0.92, respectively.

Moreover, the pure technical efficiency varied from 0.83 to 1. Also, the minimum amount of technical efficiency was calculated as 0.75. The variation in technical efficiency of orchards (0.25) shows that the farmers were aware of timing in using the inputs. Additionally, the calculation of scale efficiency shows that this amount was measured as 0.97, implying that the average size of farms was in optimal size (Mousavi-Avval et al., 2011b). The high average of scale efficiency shows that farmers utilize their inputs in the most productive scale size and considerable saving in energy from the different sources were seen. Finally, the summarized statistics for the three estimated measures of efficiency and standard deviation are presented in Table 4.

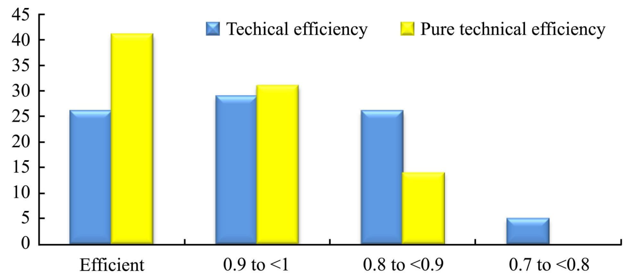

Figure 2 Efficiency score distribution of DMUs

Table 4 Average of technical, pure and scale efficiency DMUs

Particular	Average	Min	Max	SD
Technical efficiency	0.92	0.75	1	0.071
Pure technical efficiency	0.96	0.83	1	0.055
Scale efficiency	0.97	0.77	1	0.056

Mousavi-Avval et al. (2011a) applied the non-parametric method of DEA to determine the technical and pure technical efficiencies of farmers for apple production in Iran, and they found that TE and PTE were 0.79 and 0.90, respectively. Mohammadi et al. (2011) in their study for kiwifruit production in Iran reported that the technical, pure technical and scale efficiencies of farmers were calculated as 0.94, 0.99 and 0.94, respectively. Ajabshirchi (2013) reported that for corn silage in Iran, the technical, pure technical and scale efficiencies of farmers were calculated as 0.87, 0.91 and 0.95, respectively. In a study on alfalfa production in Iran, the average values of technical and pure technical scores of farmers were found to be 0.84 and 0.97, respectively (Mobtaker et al., 2012). Also, Monjezi et al. (2011) for cucumber production, Qasemi-Kordkheili et al. (2013b) for button mushroom production and Taki et al. (2012) for cucumber production reported that scale efficiency was calculated as 0.96, 0.83 and 0.94, respectively.

3.3 Energy saving from different energy inputs

Table 5 shows the actual and optimum energy requirement and saving energy for orange production based on the results of BCC model. Also, the percentage of ESTR is presented.

Table 5 Energy requirement in actual and optimal condition and energy saving

Input	Actual energy use /MJ ha^{-1}	Optimal energy requirement /MJ ha^{-1}	Saving energy /MJ ha^{-1}	ESTR /%
Water for irrigation	12072.3	10999.8	1072.5	8.8
Diesel fuel	13475.3	12272.2	1203.1	8.9
Electricity	4352.5	3485.6	866.8	19.8
Human power	2631.3	2338.7	293.6	11.1
Machinery	974.81	815.3	159.4	16.3
Chemicals	3590.0	3164.9	426.2	11.8
Fertilizers	12418.4	11328.5	1089.9	8.7
Farmyard manure	4768.8	4300.6	468.1	9.8
Total	54284.8	47705.6	5579.9	10.2

The share of the various energy inputs in the total input saving energy is illustrated in Figure 3. It is clear that, the highest contribution to the total saving energy is provided by diesel fuel (1,203.1 MJ/ha) energy inputs, followed by fertilizer (1,089.9 MJ/ha) and water for irrigation (1,072.5 MJ/ha) energy inputs. Savings energy in the different sources is possible by changing in production procedure. For example, many farmers used chemical agents to control herbs. Plowing the soil with disk harrow or moldboard plow instead of chemical agents can be a useful way to control herbs. Also, using modern tractors instead of ancient tractors and high efficiency motor pumps can help to decrease fuel consumption.

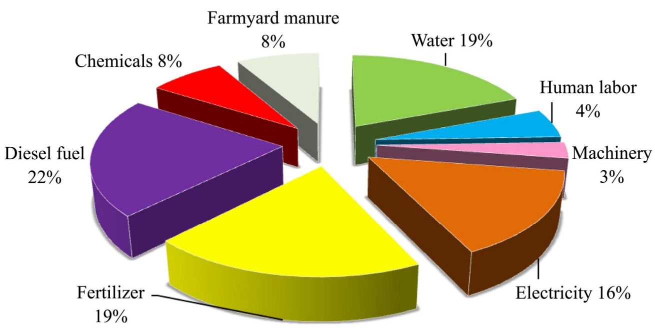

Figure 3 Distribution of energy savings from different sources in orange production

Similar results were reported by Singh et al. (2004) on optimization of energy use for wheat crop in zone 1 of Punjab. Fertilizers and diesel fuel energy inputs could be saved by 35.5%, 24% and 22.8%, respectively. Mousavi-Avval et al. (2011a) for apple production in Iran, reported that the highest contribution to the total saving energy was 78.08% from electricity followed by fertilizer (10.46%), diesel fuel (6.18%) and water for irrigation (4.11%) energy inputs. Also, Chauhan et al. (2006) reported that the contribution of fertilizer and diesel fuel energy inputs from total saving energy in paddy production were higher than other inputs. Table 6 presented PTE, the actual energy use and optimum energy requirements of these farms from different energy inputs of 44 individual inefficient farmers.

From the result of this study it is clear that orange production needs high amount of inputs such as diesel fuel, fertilizer and water for irrigation. Approximately most of orange orchards in this region are commercial and according to increasing cost of inputs optimization of energy input sources is necessary. Using information of Table 6 is useful for inefficient farmers and can help to decrease amount of inputs. As regards the orange has become the most commonly grown tree fruit in the Sari region of Iran, providing many strategies such as better water irrigating system of micro-irrigation and plus drip irrigation, using orange harvesters and determining accurate time schedule for fertilizing and accurate use of chemicals and chemical fertilizers can help to decrease energy losses. A spacing of 6 × 6 m is the standard in orchards and can be recommended to farmers. There are many problems in the close-spacing pattern, mainly is that as the trees grow and become more crowded, productivity declines and also close-spacing needs expensive pruning. Also, improving soil condition with organic matter can help to decreas the use of chemical fertilizers. Also, orange trees need to be fertilized with N P K fertilizer very soon after harvesting. Success in orange production also depends on the selection of cultivars tolerant of the climatic conditions where they are to be grown. Using a non-parametric method of DEA was very suitable to analyze farmers' practices and can help in finding the wasteful uses of energy.

Table 6 The actual energy use and optimum energy requirements for individual inefficient orange producers based on the results of BCC model

DMU	PTE	Actual energy use/MJ ha^{-1}								Optimum energy requirement/MJ ha^{-1}								ESTR /%
		Electricity	Water	Human	Machinery	fertilizers	Chemicals	Diesel	FYM	Electricity	Water	Human	Machinery	Fertilizers	Chemicals	Diesel	FYM	
1	0.83	5500	12000	2750	850	12850	3700	15000	4200	4573.8	9979.2	2286.9	706.8	10686	3076.9	12474	3492.7	16.84
2	0.97	5100	9300	2310	700	10500	2920	12600	4000	4881.2	8901	2210.9	669.9	10049.5	2794	12059.4	3828.4	6.54
3	0.84	4100	13300	2880	1280	13700	3880	15800	5400	3410.7	11064	2395.8	1064	11397	3227.7	13144	4492.2	17.34
4	0.94	0	12200	2870	1250	12900	2970	14500	4800	0	10998.3	2587.3	1126.8	11629.3	2677.4	13071.7	4327.2	18.33
5	0.85	7400	12800	2990	870	15800	3990	14600	6500	6228.5	10773.7	2516.6	732.2	13298.8	3358.3	12288.8	5471	23.79
6	0.95	4500	13340	2500	1266	13800	4400	14400	4600	4283.5	12698.3	2379.7	1205.1	13136.2	4188.3	13707.3	4378.7	8.3
8	0.99	7740	15950	2980	1289	14500	4580	13600	6000	7491.5	15438	2884.3	1247.6	14034.5	4432.9	13163.4	5807.4	9.11
10	0.95	7900	9730	2340	1100	10700	2840	11580	3800	6989.1	8608.1	2070.1	973.1	9466.2	2512.5	10244.8	3361.8	13.3
11	0.91	8100	9450	2140	956	9800	4080	12540	3600	6549.6	7641.2	1730.4	773	7924.2	3299	10139.8	2910.9	0
12	0.88	7400	10100	2780	980	13390	4180	12600	4180	6090.2	8312.3	2287.9	806.5	11019.9	3440.1	10369.8	3440.1	17.34
14	0.86	8500	12380	2660	686	11900	4260	15100	5600	7167.2	10438.8	2242.9	578.4	10034	3592	12732.3	4721.9	21.98
17	0.97	3100	12300	2740	1050	10500	3050	10500	4200	2342.3	9293.8	2070.3	793.3	7933.8	2304.5	7933.8	3173.5	24.53
21	0.89	4200	13570	2870	1110	13900	3970	15800	6000	3726.2	12039.3	2546.2	984.7	12332	3522.1	14017.7	5323.2	0
23	0.99	6600	12950	2850	1268	14000	3240	13000	5600	6461.4	12678	2790.1	1241.3	13706	3171.9	12727	5482.4	26.78
24	0.96	3400	9780	2130	1154	9500	2830	11200	3690	3022.6	8694.4	1893.5	1025.9	8445.5	2515.8	9956.8	3280.4	0
26	0.91	3200	10080	2360	1259	10800	3160	12600	4000	2825.6	8900.6	2083.8	1111.6	9536.4	2790.2	11125.8	3532	3.97
29	0.91	8350	13050	2940	960	14800	5140	15200	4600	7500.8	11722.8	2641	862.3	13294.8	4617.2	13654.1	4132.1	33.73
30	0.9	9200	13700	2600	1060	13500	3600	13300	5195	7988.3	11895.7	2257.5	920.3	11722	3125.8	11548.3	4510	5.82
35	0.96	5040	9900	2060	951	8500	3060	12700	3590	4327.8	8501.1	1768.9	816.6	7298.9	2627.6	10905.4	3082.7	0
36	0.97	5080	10200	2100	1258	10450	3300	10900	3500	3802.8	7635.7	1572	941.7	7822.8	2470.3	8159.74	2620.1	0
37	0.87	5800	15100	2960	956	15650	4460	16850	6100	5025.1	13082.6	2564.5	828.2	13559.1	3864.1	14598.8	5285	12.1
41	0.92	7200	12980	2450	1065	15800	3450	15100	5800	6597.3	11893.5	2244.9	975.8	14477.5	3161.2	13836.1	5314.5	0
42	0.9	4500	13100	2880	1069	16800	3880	16340	4690	4063.5	11829.3	2600.6	965.3	15170.4	3503.6	14755	4235	11.13
43	0.9	7100	13800	2660	983	14500	3660	15340	6500	6351.6	12345.4	2379.6	879.3	12971.7	3274.2	13723.1	5814.9	12.25
44	0.9	3400	14900	2980	984	16000	3980	16990	5900	3038.5	13316.1	2663.2	879.4	14299.2	3556.9	15183.9	5272.8	0
47	0.99	4300	10000	2400	1100	9020	2980	10460	3695	3771.5	8771	2105	964.8	7911.4	2613.7	9174.46	3240.8	12.71
50	0.92	3280	12200	3190	789	13200	3790	13000	5300	2978.8	11080	2897.1	716.5	11988.2	3442	11806.6	4813.4	0
52	0.93	4100	10240	2140	890	10600	2940	12880	4900	3278.7	8188.9	1711.3	711.7	8476.8	2351.1	10300.1	3918.5	0
56	0.91	4049	9730	2540	790	10800	3040	13850	3080	3682.9	8850.4	2310.3	718.5	9823.6	2765.1	12597.9	2801.5	17.99
57	0.87	1060	13450	3100	1200	14500	3900	16400	5580	923	11712.2	2699.4	1044.9	12626.6	3396.1	14281.1	4859	19.21
58	0.94	3100	13100	3380	500	12300	4380	16000	6540	2869	12124	3128.1	462.7	11383.6	4053.6	14808	6052.7	0
59	0.99	4800	14300	2960	1035	13500	4660	12500	5200	4675.6	13929.6	2883.3	1008	13150.3	4539.3	12176.2	5065.3	7.27
60	0.94	4550	13480	2960	560	13150	4260	14700	5500	4272.9	12659	2779.7	525.8	12349.1	4000.5	13804.7	5165	0
61	0.89	3400	12300	3240	986	14600	4440	16400	5800	2988.6	10811.7	2847.9	866.6	12833.4	3902.7	14415.6	5098.2	27.62
62	0.98	3200	10350	2540	1180	10800	3940	10500	3900	2521.9	8156.8	2001.7	929.9	8511.4	3105.1	8275.05	3073.5	14.68
63	0.81	3470	15000	3400	986	13900	4400	14700	5580	2739.2	11841	2683.9	778.3	10972.6	3473.3	11604.1	4404.8	31.34
64	0.87	3200	15000	2900	1058	13600	4600	14900	5680	2780.8	13035	2520.1	919.4	11818.4	3997.4	12948.1	4935.9	14.14
67	0.95	10570	2060	800	4400	10600	12200	2960	3690	4184.8	10053.1	1959.2	760.8	10081.6	2815.2	11603.4	3509.5	0
70	0.97	3350	14780	4490	990	12800	3490	16100	5560	3166	13968.5	4243.4	935.6	12097.2	3298.3	15216.1	5254.7	0
71	0.85	3200	11000	2840	1100	14030	4840	14300	5780	3085.7	10607.3	2738.6	1060.7	13529.1	4667.2	13789.4	5573.6	0
80	0.81	5900	14080	3380	980	14300	4380	14580	5550	4995.5	11921.5	2861.8	829.7	12107.8	3708.5	12344.8	4699.1	12.44
81	0.99	7650	15900	3380	890	13800	4380	15680	6500	6113.1	12705.6	2700.9	711.1	11027.5	3500	12529.8	5194.1	12.74
82	0.95	7200	10200	2200	1084	12900	3200	11970	4100	7085.52	10037.8	2165	1066.7	12694.8	3149.1	11779.6	4034.8	11.86
84	0.87	3500	12200	2450	968	11800	3450	12600	5330	3232.25	11266.7	2262.5	893.9	10897.3	3186	11636.1	4922.2	11.3
86	0.83	2800	13300	3400	985	12640	4500	16480	6800	2437.9	11580.3	2591.9	663.2	11005.6	3623.7	12883.7	5169.9	5.15

4 Conclusions

The energy balance between the input and output, and optimization of energy use pattern for orange production in Sari regions was investigated using DEA approach and the following conclusions are drawn:

1) The total amount of energy consumed and total output energy for orange production were 54.2 GJ/ha and 59.2 GJ/ha, respectively. Among input energy sources, diesel fuel and chemical fertilizers had the highest share, respectively. Also, energy ratio and energy productivity were calculated as 1.09 and 0.57 kg/MJ, respectively.

2) Results obtained by the application of DEA technique show that among 86 farmers that was analyzed, 41 (47% of total farms) farms had pure technical efficiency and 26 (30% of total farms) farms had technical efficiency. Additionally, the average of scale efficiency was calculated as 0.97.

3) Differences between present and target amounts of inputs showed that on average farmers can save 5579.9 MJ/ha and the highest contribution to the total saving energy was provided by diesel fuel followed by fertilizer and water for irrigation energy inputs.

4) Considerable waste of input energies in many practices such as water irrigation and machinery wastage led to the decrease in farm efficiency. Many of the orchards analyzed were old with unsatisfactory yield and high energy consumption, thus establishing new orchards by cutting old trees and planting new orange sapling is suggested.

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References

Anonymous. 2010. Food and Agricultural Organization (FAO).

Ajabshirchi, Y. 2013. Energy input-output, optimization of energy consumption with DEA approach for corn silage production in Iran. *International Journal of Agriculture and Crop Sciences,* 5(1): 80-88.

AvkIran, N.K. 2001.Investigating technical and scale efficiencies of Australian Universities through data envelopment analysis. *Socio–Economic Planning Sciences*. 35(1): 57–80.

Bahrami, H., M. Taki, and N. Monjezi. 2011. Optimization of energy consumption for wheat production in Iran using data envelopment analysis (DEA) technique. *African Journal of Agricultural Research*, 6(27): 5978-5986.

Bames, A. 2006. Does multi-functionality affect technical efficiency? A non–parametric analysis of the Scottish dairy industry. *Journal of Environ Management*, 80(4): 287-294.

Banker, R. D., A. Charnes, and W. W. Cooper. 1984. Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis (DEA). *Management Science,* 30(9): 1078-1092.

Charnes, A. W, Cooper, and E. Rhodes. 1978. Measuring the efficiency of decision making units. *European Journal* of Operational Research 2(5): 429–444.

Chauhan, N. S., P. K. J. Mohapatra, and K. P Pandey. 2006. Improving energy productivity in paddy production through benchmarking-an application of data envelopment analysis. *Energy Conversion and Management,* 47(9): 1063-1085.

Cooper, W, L. M. Seiford, and K. Tone. 2004. Data envelopment analysis, a comprehensive text with models, applications, references and DEA-solver software. Massachusetts, USA: *Kluwer Academic Publishers.*

Esengun, K., G. Erdal, O. Gunduz, and H. Erdal. 2007. An economic analysis and energy use in stake-tomato production in Tokat province of Turkey. *Renewable Energy*, 32(11): 1873-1881.

Galanopoulos, K., S. Aggelopoulos, I. Kamenidou, and K. Mattas. 2006. Assessing the effects of managerial and production practices on the efficiency of commercial pig farming. *Agricultural Systems*. 88 (2): 125-141.

Gezer, I., M. Acaroglu, and H. Haciseferogullari. 2003. Use of energy and labor in apricot agriculture in Turkey. *Biomass Bioenergy*; 24(3): 215–219

Hu, J. L., and C. H. Kao. 2007. Efficient energy-saving targets for APEC economies. *Energy Policy*, 35(1): 373-382.

Kizilaslan, H. 2009. Input–output energy analysis of cherries production in Tokat Province of Turkey. *Applied Energy*, 86(7): 1354-1358.

La Rosa, A. D., G. Siracusa, and R. Cavallaro. 2008. Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming. *Journal of Cleaner Production,* 16(17): 1907-1914.

Mobtaker, H. G., A. Akram, A. Keyhani, and A. Mohammadi. 2012. Optimization of energy required for alfalfa production using data envelopment analysis approach. *Energy for Sustainable Development,* 16(2): 242–248.

Mohammadi, A., S. H. Rafiee, S. S. Mohtasebi, S. H. M. Avval, and H. Rafiee. 2011. Energy efficiency improvement and input cost saving in kiwifruit production using Data Envelopment Analysis approach. *Renewable Energy*, 36(9): 2573-2579.

Mohammadi, A., Sh. Rafiee, H, Mohtasebi and H, Rafiee. 2010. Energy inputs - yield relationship and cost analysis of kiwifruit production in Iran. *Renewable Energy*, 35(5): 1071-1075.

Mohammadshirazi, A., A. Akram, S. Rafiee, S. H. M. Avval, and E. B. Kalhor. 2012. An analysis of energy use and relation between energy inputs and yield in tangerine production. *Renewable and Sustainable Energy Reviews*, 16(7): 4515-4521.

Monjezi, N., M. Taki, and M. J. Sheikhdavoodi. 2011. Energy use pattern and optimization of energy consumption for greenhouse cucumber production in Iran using Data Envelopment Analysis (DEA*). Modern Applied Science*, Vol. 5, No. 6.

Mousavi-Avval, S. H., S. Rafiee, A. Jafari, and A. Mohammadi. 2010. Improving energy use efficiency of canola production using data envelopment analysis (DEA) approach. *Energy*, 36(5): 2765-2772.

Mousavi-Avval, S. H., S. Rafiee, and A. Mohammadi. 2011a. Optimization of energy consumption and input costs for apple production in Iran using data envelopment analysis. *Energy*, 36(2): 909-916.

Mousavi-Avval, S. H., S. Rafiee, A. Jafari, and A. Mohammadi. 2011b. Optimization of energy consumption for soybean production using Data Envelopment Analysis (DEA) approach. *Applied Energy,* 88(11): 3765-3772.

Namdari, M., A. Asadi-Kangarshahi, and N. Akhlaghi-Amiri. 2011. Input-output energy analysis of citrus production in Mazandaran province of Iran. *African Journal of Agricultural Research*, 6 (11): 2558-2564.

Nassiri, S. M, and S. Singh. 2009. Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. *Applied Energy*, 86(7): 1320-1325.

Ozkan, B, H. Akcaoz, and F. Karadeniz. 2004. Energy requirement and economic analysis of citrus production in Turkey. *Energy Conversion Manage*, 45(11): 1821-1830.

Qasemi-Kordkheili, P., N. Kazemi, A. Hemmati, and M. Taki. 2013a. Energy consumption, input–output relationship and economic analysis for nectarine production in Sari region, Iran. *International Journal of Agriculture and Crop Sciences,* 5(2): 125-131.

Qasemi-Kordkheili, P., M. A. Asoodar, M. Taki, and M. M. Keramati-E-Asl. 2013b. Energy consumption pattern and optimization of energy inputs usage for button mushroom production. *International Journal of Agriculture: Research and Review,* 3(2): 361-373.

Rahbari, H., A, Mahmoudi, and Y. Ajabshirchi, 2013. Energy consumption and application of parametric method for tomato production in Iran. *International Journal of Agriculture and Crop Sciences*. 5. 89-94.

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

Sarica, K., and I. Or. 2007. Efficiency assessment of Turkish power plants using data envelopment analysis. *Energy*, 32(8): 1484-1499.

Sartori, L., B. Basso, M. Bertocco, and G. Oliviero. 2005. Energy use and economic evaluation of a three year crop rotation for conservation and organic farming in NE Italy . *Biosystems Engineering*, 91(2): 245-256.

Scheel, H. 2000. EMS: efficiency measurement system user's manual, Ver. 1.3, Operations Research and Wirtschaftsinformatik, University of Dortmund. Dortmund, Germany. http://www.wiso.uni-dortmund.de/lsfg/or/scheel/ems. (accessed 2009)

Singh, G, S. Singh, and J. Singh. 2004. Optimization of energy inputs for wheat crop in Punjab. *Energy Conversation Management*, 45(3):453-465.

Singh, J. M. 2000. On farm energy use pattern in different cropping systems in Haryana, India. Germany: Int Inst of Management University of Flensburg, *Sustainable Energy Systems and Management,Master of Science.*

Singh, A., A. A. Naqvi, and S. Singh. 2002. Citrus germplasm cultivars and rootstock. 1st Edition, Kalyani Publisher, India, pp. 5-60.

Strapatsa, A. V., G. D. Nanos, and C. A. Tsatsarelis. 2006. Energy flow for integrated apple production in Greece. *Agriculture, Ecosystems & Environment*, 116(3): 176-80.

Tabatabaie, S. M. H., S. H. Rafiee, A. Keyhani, and M. A. Heidari. 2013. Energy use pattern and sensitivity analysis of energy inputs and input costs for pear production in Iran. *Renewable Energy*, 51: 7-12.

Taki, M. Y, Ajabshirchi, and A. Mahmoudi. 2012. Application of Parametric and Non-parametric Method to Analyzing of Energy Consumption for cucumber Production in Iran. *Modern Applied Science*, 6(1): 75-87.