Modeling and optimization of energy consumption for grapefruit production in Iran

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Abstract: Grapefruit production has increasing rate in recent years. In this study a non-parametric method of Data Envelopment Analysis (DEA) has used to estimate the energy efficiency of grapefruit production orchards in Sari region of Iran. Additionally, the impacts of energy inputs on grapefruit yield were determined. Data were collected using a face-to-face questionnaire method from 71 orchardists in winter 2014. The results showed that the total energy consumption was 49.8 GJ/ha and chemical fertilizers by 28% of this quantity had the highest share on total input energy. The results of CCR and BCC models of DEA showed that from total of 71 orchardists, only 21 orchards were technically efficient by efficiency score of one and 43 orchards were pure technical efficient. The average of technical efficiency and pure technical efficiency scores calculated as 0.94 and 0.86, respectively. The results of Cobb-Douglas production function showed that chemical fertilizer had the highest impact on yield level among all inputs. Additionally, the impact of indirect and direct energy in grapefruit production was significant at a 1% probability level with 0.84 and 0.89 regression coefficients, respectively.

Keywords:data envelopment analysis, energy indices, energy saving, grapefruit production

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1 Introduction

Citrus fruits are among the most abundant crops in the world with an annual production of over 88 Mt. Almost 33% of the crops, including orange, lemons, grapefruit and mandarins, are industrially processed for juice production, where about half of the processed citrus including peels, segment membrane and seeds end up as wastes (Mohammadshirazi et al., 2012).The grapefruit (*Citrus paradise*) is one of the new cultivated trees in the north of Iran and it is primarily used for its juice.Based on the FAO statistics Iran is ranked in 15th place in the world with 48,900 t grapefruit per years (FAO, 2013). Nearly 2,380 ha of orchards associated to grapefruit trees, is in Sari region and its rate was increasing in recent years (Anon, 2013). Energy in agriculture is important in terms of crop production and agro-processing for value adding. Human, animal and machinery is extensively used for crop production in agriculture. Energy use depends on mechanization level, the quantity of active agricultural worker and cultivable land. Efficient use and study impacts of these energies on crop production help to achieve increased production and productivity and help the economy, profitability and competitiveness of agricultural sustainability of rural communities (Banaeianand Namdari, 2011). Energy efficiency improvement is a key indicator for sustainable energy management and energy, economics, and the environment are mutually dependent. Agriculture is an energy user and energy supplier in the form of bioenergy and this subject represents close relationship between agriculture and energy (Hemmati et al., 2013). Data Envelopment Analysis (DEA) is a non-parametric technique of frontier estimation which is used extensively in many settings for measuring the efficiency and benchmarking of decision

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making units (DMUs) (Mohammadi et al., 2011). In recent researches application of integrated production methods is recently considered as a means to reduce production costs, to efficiently use human power and other inputs and to protect the environment (Samavatean et al., 2011). Parametric approaches have been extensively used to estimate input-output relationships in energy sector among agricultural investigators in order to study the efficiency of resource allocation. The most celebrated of them is the Cobb-Douglas production function. Many studies have been done in energy sector such as Strapatsa et al. (2006) on apple production in Greece, Sartori et al. (2005) on apricot and plum in Italy, Tabatabaie et al. (2013), Hemmati et al. (2013) and QasemiKordkheili et al. (2014) on pear, olive and orange production in Iran, respectively.

With considering lack of study on energy use efficiency for grapefruit production in Iran, attempt was made to determine the technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) of grapefruit orchards by a non-parametric method. Additionally, the Cobb-Douglas production function was used to find the relation between inputs and output energies.

Therefore, the present study was undertaken to discriminate efficient orchardists from inefficient ones for grapefruit production in Sari region of Iran and determining the optimum amounts of energy inputs for grapefruit production. Also, the impacts of different energy inputs on grapefruit yield were evaluated to reveal the importance of the use of each input on yield. Finally, the results of this study represent the recommendations for grapefruit production regarding to the optimum use of energy and minimum reduction on grapefruit yield.

2 Materials and methods

2.1 Sampling design

This study was conducted in Sari Region, in the north of Iran within 35°58 and 36°50 north latitudes and 52°56 and 53°59 east longitudes (Anon, 2013). The prevailing climate of the studied area is a typical Mediterranean climate with the precipitation of 620 mm, temperature of 18°C, soil water regime of xeric and soil temperature regime of thermic. Most precipitations are during the winter and spring seasons (Soil Survey Staff, 1999). The average orchards were 2 ha and most of them were approximately eight years old and all of the orchards were single-crop grapefruit orchards. The initial data were collected from grapefruit orchardists using face-to-face questionnaire in winter 2014. The size of each sample was determined using Equation 1 (Kizilaslan, 2009).

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

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%). Thus the calculated sample size in this study was determined to be 71 grapefruit farms.

2.2 Energy equivalents of inputs and output

Grapefruit is an important horticultural commodity in citrus family after orange, tangerine and lemon in Iran. In addition to orange, tangerine and nectarine production many farmers tend to produce grapefruit in Sari region. For sampling, the stratified sampling method was used and the physical data on inputs and output were then converted into energy equivalent using energy equivalent coefficients. The inputs may be in the form of electricity, human power, machinery, farmyard manure, diesel fuel, chemical, chemical fertilizers and water for irrigation. The energy equivalent may thus be defined as the energy input taking into account all forms of energy in agricultural production (Mousavi-Avval et al., 2011a). 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).

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

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).

In order to calculate the amount of energy used by each orchardist, each input source was converted into its energy equivalent as listed in Table 1. The amounts of inputs and output were calculated per hectare for each orchard and then these data were multiplied by the coefficient of energy equivalent of each energy input (Table 1). As can be seen in Table 1, the total energy consumption and grapefruit yield were calculated about 49828.8 MJ/ha and 27170.2 kg/ha, respectively.

Table 1 Energy coefficients and energy inputs/output in various operations of grapefruit production

Item	Energy equivalent, MJ/unit	References	Quantity per area unit, ha)	Total energy equivalent, MJ/ha
Input				
1.Diesel fuel (l)	47.8	(Singh, 2002)	243.9	11634.5
2.Electricity (kWh)	11.93	(Mohammadi and Omid, 2010)	193.9	2303.68
3.Human power (h)	1.96	(Nassiri and Singh, 2009)	1041.3	2044.86
4. Irrigation, m^3	1.02	(Mousavi-Avval et al., 2011b)	10855.5	11072.2
5.Machinery, kg	62.7	(Mousavi-Avval et al., 2011a)	3964.1	894.3
6.Fertilizer, kg				
Nitrogen	66.44	(Kitani, 1999)	121.5	8079.4
Phosphate (P_2O_5)	12.44	(Mohammadi and Omid, 2010)	296.8	3692.3
Potassium (K_2O)	11.15	(Mohammadi and Omid, 2010)	200.4	2234.5
7. Manure, kg	0.3	(Hemmati et al., 2013)	14811.1	4443.33
8.Chemicals, kg				
Herbicides	238	(Rafiee et al., 2010)	9.3	2213.4
Pesticides	199	(Namdari et al., 2011)	2.99	595.01
Fungicide	92	(Ozkan et al., 2004)	6.75	621
Output				
Grapefruit, kg	1.9	(Kitani, 1999)	27170.2	51623.8

The input energy indices in agriculture are divided into two main groups of energy; direct energy, indirect energy (Asakereh et al. 2010). The direct energy requirements are needed for land preparation, cultivation, irrigation, harvesting, post-harvest processing, food production, storage and the transport of agricultural inputs and outputs. Indirect energy needs are in the form of sequestered energy in fertilizers, herbicides, pesticides, and insecticides (FAO, 2000). So in this study we classify input sources as, direct energy which includes human power, diesel fuel, water for irrigation, electricity; and indirect energy which includes chemical fertilizers, farmyard manure, chemicals, and machinery.

2.3Data envelopment analysis (DEA)

In recent years, the most of studies on optimization of energy and input usage employs the non-parametric techniques such as DEA. The main advantage of DEA approach compared to parametric ones is that it does not require any prior assumption on the underlying functional relationship between inputs and outputs (Mousavi-Avval et al., 2011b). 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., 2011b). Production units are termed DMUs in DEA terminology. DEA defines efficiency in three different forms: TE, PTE and SE. Technical efficiency (TE) is basically a measure by which DMUs are evaluated for their performance relative to other DMUs. Its value influenced by SE, which quantifies the effect of the presence of variable returns to scale in the DMUs. Pure Technical Efficiency (PTE) is the TE that the effect of SE has removed (Banaeianand Namdari, 2011). The input variables were defined as: human power, machinery, chemicals, water for irrigation, chemical fertilizers and diesel fuel, and the grapefruit yield is the single output variable.

2.4 Technical efficiency

Based on the Equation 3 TE is a measure by which DMUs are evaluated for their performance related to the performance of other DMUs in consideration (Cooper et al., 2004).

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + ... + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + ... + v_m x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_s x_{sj}} \quad (3)$$

Where, u_r, is the weight (energy coefficient) given to the 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 the number of inputs (*s = 1, 2, .., m*) and *j*, represents *jth* of DMUs (*j = 1, 2, . . ., k*). Equation (3) is a fractional problem, so it can be translated into a linear programming (LP) problem which developed by Charnes et al. See Equation 4 please. (1978) (Avkiran, 2001):

$$\text{Maximize} \quad \theta_j = \sum_{r=1}^{n} u_r y_{rj} \quad (4)$$

Subjected to

(I) $\sum_{r=1}^{n} u_r y_{rj} - \sum_{s=1}^{m} v_s x_{sj} \le 0$

(II) $\sum_{s=1}^{m} v_s x_{sj} = 1$ for all *j* = 1, 2, …, k

(III) $u_r \ge 0$, for all *r* = 1, 2, …, n

(IV) $v_s \ge 0$, for all *s* = 1, 2, …, m

Where θ is the technical efficiency and *i* represents *i*th DMU. Equation 4 is known as the input oriented CCR DEA model, assuming constant returns to scale (CRS) (Avkiran, 2001). So, the large producers are just as efficient as small ones in converting inputs to output.

2.5Pure technical efficiency

PTE is the BCC (Banker-Charnes-Cooper) and calculates the TE of DMUs under variable return to scale conditions. PTE can separate technical and scale efficiencies. The main advantage of this model is that scale inefficient orchards are only compared to efficient orchards of a similar size (Mousavi-Avval et al., 2011a). The dual model is derived by construction from the standard inequality form of linear programming.It can be expressed by Dual Linear Program (DLP) as following Equation 5 (Mousavi-Avval et al., 2011a):

$$\text{Maximize} \quad z = uy_i - u_i \quad (5)$$

Subjected to

(I) $vx_i = 1$

(II) $-vX + uY - u_0 e \le 0$

(III) $v \ge 0, u \ge 0$ and u_0 is unconstrained in sign.

Where z and u_0 are scalar and free in sign, *u* and *v* are output and input weight matrixes, and *X* and *Y* are corresponding output and input matrixes, respectively. The letters x_j and y_j refer to the inputs and output of *j*th DMU.

2.6 Scale efficiency

Using BCC model, the pure technical efficiency of a DMU is measured relative to an efficient frontier at the same scale size. BCC is modeled by setting the convexity constraint. In this case, the scale efficiency is determined by measuring the divergence between the actual scale size and the most productive scale size (Banaeianand Namdari 2011). The relationship between SE, TE and PTE can be expressed as following Equation 6 (Mousavi-Avval et al., 2011b):

$$ScaleEfficiency = \frac{Technicalefficiency}{PureTechnicalefficiency} \quad (6)$$

The SE helps orchardists to find the effect of orchard size on efficiency of production. Simply, it indicates that some part of inefficiency refers to inappropriate size of DMU, and if DMU moved toward the best size the overall efficiency (technical) can be improved at the same level of technologies (inputs) (Nassiri and Singh, 2009). If an orchard is fully efficient in both the TE and PTE scores, it is operating at the most productive scale size. On the other hand if an orchard has the high PTE score, but a low TE score, then it is locally efficient but not globally efficient due to its scale size. Thus, it is reasonable to characterize the SE of a DMU by the ratio of the two scores (Mobtaker et al., 2010)

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 ESTR index calculated as Equation 7:

$$ESTR_j = \frac{(\text{Energy Saving Target})_j}{(\text{Actual Energy Input})_j} \quad (7)$$

2.7 Cobb-Douglas production function

The production function specifies the output of an orchard for all combinations of input energy sources. The Cobb-Douglas production function yielded the best estimates in terms of statistical significance and expected signs of parameters (Sarica and Or, 2007), is expressed as Equation 8:

$$Y = f(x) \exp(u) \quad (8)$$

This function has been used by several authors to examine energy input and yield relation (Hemmati et al., 2013;Nabavi-Pelesaraei et al., 2014) and can be written in linear form as Equation 9:

$$\ln Y_i = \alpha_0 + \sum_{j=1}^{n} \alpha_j + \ln(X_{ij}) + e_i \quad i = 1,2,3,\ldots \quad (9)$$

Where Y_i denotes the yield level of the *i*'th orchardist, X_{ij} is the vector inputs used in the production process, α_0 is the constant term, α_j represents coefficients of inputs which are estimated from the model and $e_i$is the error term. In this study with assumption that, when the energy input is zero, the crop production is also zero and the yield is a function of input energies, Equation (8) can be expressed in Equation 10Hemmati et al. (2013):

Model I:

$$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + e_i \quad (10)$$

Where Y_i denotes the yield level of the *i*'th farmer, X_1 is water energy, X_2 is human power energy, X_3 is machinery energy, X_4 is farmyard manure energy, X_5 is chemical fertilizer energy, X_6 is diesel fuel energy and $X_7$is chemical biocide energy. With respect to this pattern, first, the impact of the energy of each input on the grapefruit yield was studied and second, the impact of direct and indirect energies, and renewable and non-renewable energies on the production were studied. For this purpose, Cobb-Douglas function was determined in the following Equation 11 and Equation 12 (Tabatabaie et al., 2013):

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

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

Where Y_i denotes the yield level of the *i*'th farmer, β_j and γ_j are coefficient of exogenous variables. DE, IDE, RE, and NRE are direct, indirect, renewable and non-renewable energies, respectively.

Basic information on energy inputs of grapefruit production were entered into Excel 2013 spreadsheets, and Frontier Analyst 4 software programs. Additionally, because of homogenous condition of the surveyed area it allows more validity to the assumptions of DEA.

3 Results and discussion

3.1 Analysis of energy input and output

Grapefruit is an ever green tree and its fruit is low in acidity. A mature grapefruit tree can grow as high as 5 m and ready to produce fruit after 2 to 3 years. Among the inputs sources, chemical fertilizers had the highest share on input energy. In grapefruit production it is common to use about 618.8 kg/ha of chemical fertilizers including nitrogen, phosphate and potassium with total energy equivalent of 14006.2 MJ/ha.There are several different nutrients that a grapefruit tree needs in order to produce fruits with marketable quality. Among these nutrients, nitrogen (N) is the most important element for a grapefruit tree. As a macronutrient, nitrogen is a major nutrient that will help to tree growth and increase the chances to achieve maximum yield. The energy of diesel fuel placed after chemical fertilizers energy regarding share on total input energy. Generally, diesel fuel was used for diesel motor water pumps and tractors in the orchards. The average energy of diesel fuel was 11634.5 MJ/ha and followed by water for irrigation and total manure energy with 11072.2 and 4443.33 MJ/ha, respectively. In addition to the good climatic condition and proper rainfall in this area grapefruit trees need water, especially during drier months of the year and in primary years of growth. The flood irrigation system is a common system for irrigating and due to water wastage in this system changing the irrigation system is an important way to decrease the energy usage. Change the watering system in this area is one of the main ways to decrease energy consumption. Also, chemicals, electricity, human and machinery energies had the lowest amount of total energy usage. The grapefruit orchards face the problem of pest infestation, which can become a serious problem if it is not controlled properly.Many practices such as farmyard manure and chemical fertilizer scattering and harvesting has been done by human power. On the other hand, human power is used for harvesting and also, the winter plowing has done by human power. Electricity energy was used for many electrical water pumps. The main usage of machinery was related to the tractors. Tractors were used for plowing and human and grapefruit transfer. To sum it up, total input and output energies are 51623.8 MJ/ha and 49827.47 MJ/ha. The distribution of energy source inputs used in grapefruit production illustrated in Figure 1.

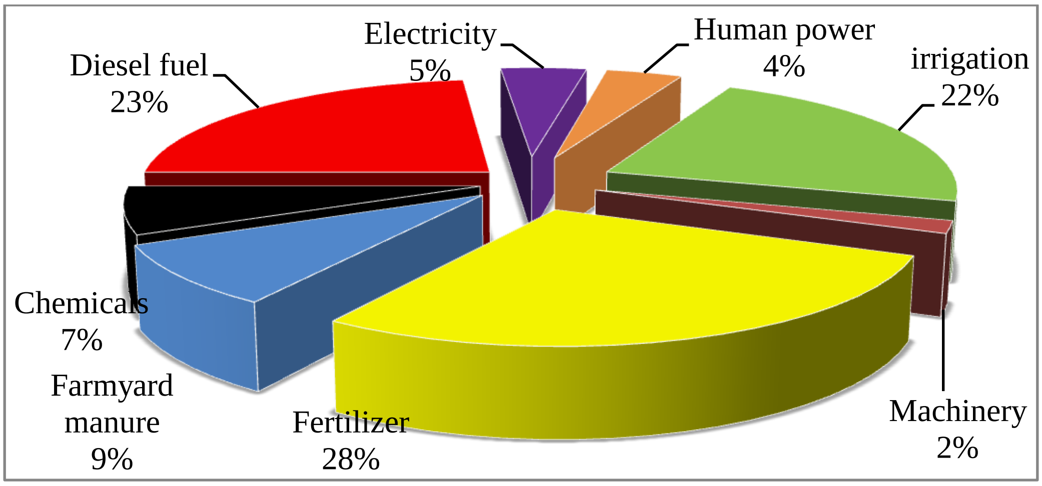

Figure 1Shares of energy input sources in total input energy for grapefruit production

Ozkan et al. (2004) in their study on orange production in Turkey revealed that the chemical fertilizers and diesel fuel were the highest in the total energy consumption. Additionally, Mohammadshirazi et al. (2012) found that chemical fertilizers had the highest energy consumption for tangerine production in Mazandaran province of Iran.The improvements of energy indices for grapefruit production are presented in Table 2. The finding of this study showed that fertilizer has the highest contribution of total energy consumption, like other citrus family commodities. So, using more farmyard manure and organic matters to protect the environment and maintain the sustainable agriculture is an important factor.

Table 2Energy forms and indices in grapefruit production

Items	Unit	Grapefruit
Energy use efficiency	–	1.03
Energy productivity	kg/MJ	0.42
Net energy	MJ/ha	9604.6
Direct energy [a]	MJ/ha	27055.24
Indirect energy [b]	MJ/ha	22773.2
Renewable energy [c]	MJ/ha	17560.39
Non–renewable energy [d]	MJ/ha	32268.03
Total energy input	MJ/ha	49827.47

Note: a. Includes human power, diesel fuel, water for irrigation, electricity;

b. includes chemical fertilizers, farmyard manure, chemicals, machinery;

c. Includes human power, farmyard manure, water for irrigation;

d. Includes diesel fuel, electricity, chemicals, chemical fertilizers, machinery.

The overall energy ratio (Energy use efficiency) was calculated as 1.03 and energy productivity was calculated as 0.54 kg/MJ which means that for every 1 MJ of energy consumed farmers can produce 0.65 kg of grapefruit. Ozkan et al. (2004) calculated the energy ratio as 1.25 for orange production in Turkey. In similar research Namdari et al. (2011) and QasemiKordkheili et al. (2014) reported that the energy ratio and the energy productivity of orchards for orange production was 0.99, 0.52 kg/MJ and 1.09, 0.57 kg/MJ in Mazandaran province of Iran, respectively. To improve energy ratio orchardists have to decrease consumption of main inputs that has higher amount of consumption such as fertilizer and diesel fuel. Also, specific energy and net energy were measured as 1.53 MJ/kgand 8974.9 MJ/ha, respectively. The distribution of energy consumption from direct, indirect, renewable and non-renewable energy resources was also investigated. The results revealed that from total input energy 10866.6 and 26614.8 MJ/ha were in the form of direct and indirect, and 12072.6 and 25408.2 MJ/ha were in the form of renewable and non-renewable energies, respectively. The share of non-renewable energy form is lower than other measured amounts for other crops such as 86% of total energy for pear production in Iran (Tabatabaie et al., 2013), 73% of total energy for kiwifruit production in Iran (Mohammadi et al., 2009) and about 91% for olive production in Iran (Hemmati et al. 2013). The high ratio of non-renewable in the total used energy inputs causes negative effects on the sustainability in agricultural production and environmental aspects. Therefore, it is important to better utilize the renewable sources for making up for the increasing energy deficit, as they represent an effective alternative to fossil fuels for preventing resources depletion and for reducing air pollution (Omid et al., 2010).

3.2Efficiency estimation of orchardists

DEA is a well-established methodology to evaluate the relative efficiencies of a set of comparable entities or production units by some specific mathematical programming models. Production units are termed (DMUs) in DEA terminology (Omid et al., 2010).The results of BCC and CCR models of DEA showed that from total of 71 orchardists, based on CCR results, only 21 orchards were efficient by efficiency score of 1. Also, from the results of BCC model 43 orchards were efficient.

The average of PTE and TE calculated as 0.94 and 0.86, respectively. Moreover, the PTE varied from 0.94 to 1. Also, the minimum amount of the TE was calculated as 0.86. The pure TE score of a producer that is less than one indicates that, at present, he is using more energy than required from the different sources (Omid et al., 2010).QasemiKordkheili and Nabavi-Pelesaraei (2013) applied the non-parametric method of DEA to determine the technical and pure technical efficiencies of orchardists for nectarine production in Iran; the average of technical, pure technical and scale efficiency of grapefruit orchards were 0.85, 0.99 and 0.86, respectively.Nabavi-Pelesaraei et al. (2014) computed the average of TE, PTE and SE of about four orange orchardists by DEA method, respectively. The summarized statistics for the three estimated measures of efficiency are presented in Table 3. The wide range in the TE of farmers shows that all the farmers were not aware of the on-time usage of the inputs and did not apply them at the proper amount (Mohammadi et al., 2011). This issue led to energy wastage and new policy to improve input sources usage is necessary. Additionally, the calculation of SE shows that this amount was measured as 0.86, implying that the average size of farms was in optimal size.

Table 3Average efficiency indices for grapefruit orchards

Particular	Average	SD	Min	Max
Technical efficiency	0.86	0.143	0.67	1
Pure technical efficiency	0.94	0.056	0.88	1
Scale efficiency	0.88	0.17	0.74	1

Results obtained by the application of the input-orientated BCC and CCR models in the form of efficiency score distribution are illustrated in Figure 2. The high average of SE shows that farmers utilize their inputs in the most productive scale size and considerable saving in energy from the different sources were seen.

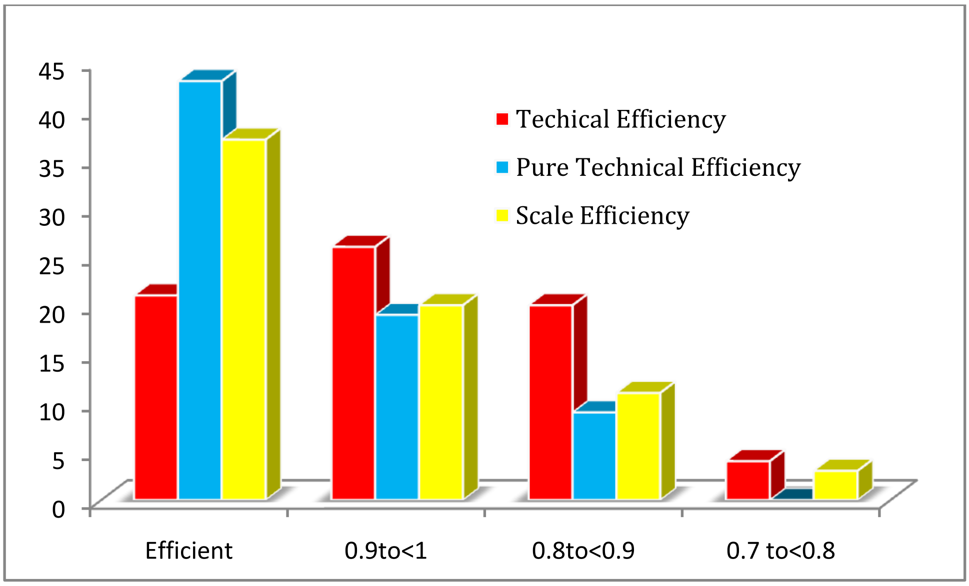

Figure 2Efficiency score distribution of grapefruit orchards.

The result showed that 21 orchards were efficient. Also, 26 orchards were between 0.9 to < 0.99 and 20 orchards were between 0.8 to < 0. 9 and four remain orchards efficiency was lower than 0.7.

3.3 Optimum energy requirement and saving energy

Optimization is an important tool to maximize the amount of productivity which can significantly impact the energy consumption (Mousavi-Avval et al., 2011b). The optimum energy requirement and saving energy for grapefruit production based on the results of BCC model is shown in Table 4. The total energy saving was computed as 4228.17 MJ/ha.

Table 4Energy requirement in actual and optimal condition and saving energy

Input	Actual energy use, MJ/ha	Optimal energy requirement, MJ/ha	Saving energy, MJ/ha	ESTR, %
Diesel fuel	11634.5	10457.4	1177.1	10.11
Electricity	2303.68	1980.9	322.78	14.01
Human power	2044.86	1880.9	163.96	8.01
irrigation	11072.2	10459.6	612.6	5.53
Machinery	894.3	810.8	83.5	9.339
Fertilizer	14006.2	12300.0	1706.2	12.18
Farmyard manure	4443.33	4300.9	142.43	3.20
Chemicals	3429.4	3109.8	319.6	9.319
Total	49828.8	45300.4	4228.17	9.32

As it can be seen from Table 4, the highest contribution to the total savings energy belongs to chemical fertilizers with 40.3% of total saving energy. It can be realized that there is a large amount of wastage in fertilizing and the main reasons may be that the farmers spread fertilizers by hand and most of them do not have suitable information about time of fertilizing. Diesel fuel is the second input that hasa large amount of energy saving with 20.3%. It can be justified that most of the tractors and water pumps are obsolete and it will cause fuel wastage. Machinery is another input source that have high amount of saving energy with 11.8%. The total energy saving is 4228.17 MJ/hathatis higherin comparison to apple production (Mousavi-Avval et al., 2011b) and orange production in Iran (Nabavi-Pelesaraei et al., 2014). The shares of energy inputs on total saving energy are shown in Figure 3.

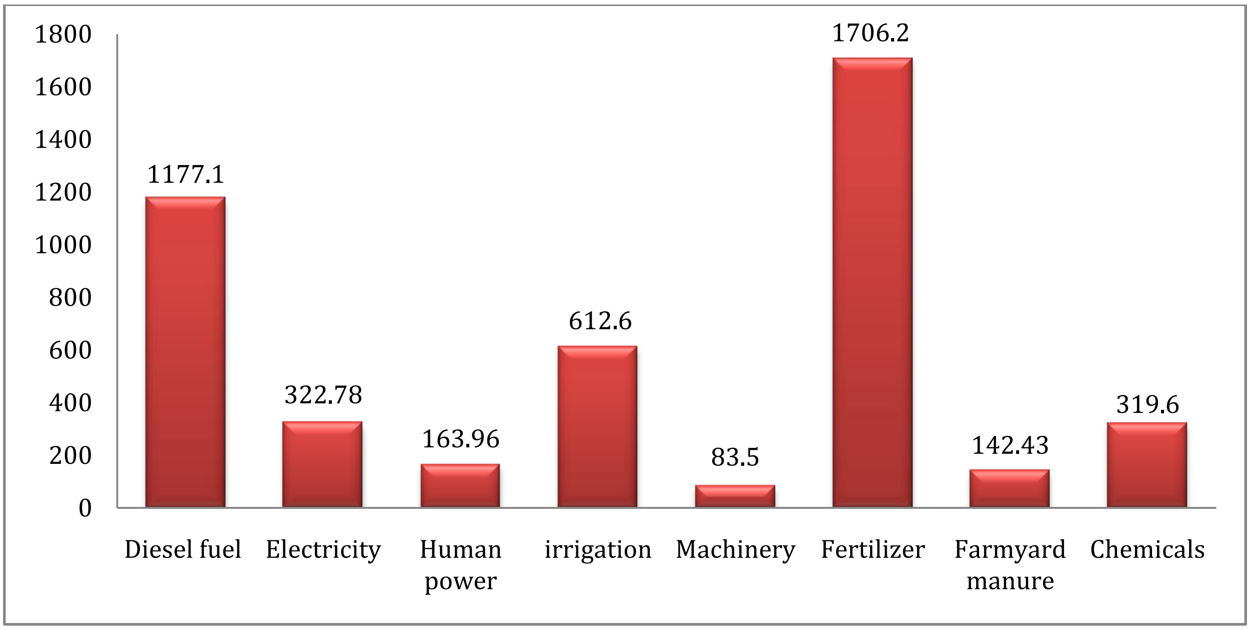

Figure 3Distribution of energy input sources on total saved energy for grapefruit production

3.4 Econometric modeling of energy inputs

To estimate the energy of input sources and their individual relationships to grapefruit yield the Cobb-Douglas production function was applied. Grapefruit yield (endogenous variable) was assumed to be a function of seven inputs used in production including; water for irrigation, human power, machinery, chemical fertilizer, diesel fuel, chemicals and farmyard manure (exogenous variables). The R^2 value (coefficient of determination) of this equation was determined to be 0.84 meaning that 84% of the variability in the energy input sources can be described by this model. The results of econometric estimation are shown in Table 5.

Table 5Econometric estimation results of energy inputs for grapefruit production

	Coefficient	*t*-ratio
Endogenous variable: yield		
Model I: $\ln = \alpha_1\ln X_1 + \alpha_2\ln X_2 + \alpha_3\ln X_3 + \alpha_4\ln X_4 + \alpha_5\ln X_5 + \alpha_6\ln X_6 + \alpha_7\ln X_7$		
Exogenous variables:		
Water for irrigation	0.44	2.98**
Human power	0.09	0.94
Machinery	-0.03	-0.75
Chemical fertilizer	0.51	5.57**
Diesel fuel	0.43	1.92
Chemicals	0.03	0.28
Farmyard manure	0.20	3.88*
R^2	0.84	
Returns to scale	0.973	

Note: * and ** indicate significance at 5% and 1% probability levels, respectively.

Table 5 shows that chemical fertilizer and water for irrigation contributed significantly to productivity at 1% probability level. Additionally, chemical fertilizer had the highest impact (0.51) among all inputs. It indicates that 1% increase in the water or chemical fertilizer led to 51% increase in yield energy in these conditions of production.Hemmati et al. (2013) reported that chemical fertilizers had the highest contribution on olive yield in flat land orchards. Rafiee et al. (2010) in an estimated econometric model on apple production reported that human power, chemical fertilizers, farmyard manure, water for irrigation and electricity energies had significant impacts on improving yield. Mohammadi et al. (2009) in another study on kiwifruit reported that human power, machinery, chemical fertilizers and water energies increase yield with significant additional impact. It is clear that level of yield in grapefruit production in Sari region strongly depends on chemical fertilizers. According to the increasing of inputs costs in Iran, exact timing of fertilizing and optimization the amount of fertilizers are important factors and need to consider some recommendations such as reducing chemical fertilizer consumption and instead using more farmyard manure due to improving the sustainable agriculture.Although drop irrigating system has high fixed costs but it can decrease the total water energy wastage. Table 6 presents the results of econometric models of direct, indirect, renewable and non-renewable forms of energy.

Table 6Econometric estimation results of energy forms

Exogenous variables	Coefficient	*t*-ratio
Model II: $\ln Y_i = \beta_1 \ln(DE) + \beta_2 \ln(IDE) + e_i$		
1. Direct energy	0.91	1.81**
2. Indirect energy	0.86	9.91**
R^2	0.75	
RTS	0.997	
Model III: $\ln Y_i = \gamma_1 \ln(RE) + \gamma_2 \ln(NRE) + e_i$		
1. Renewable energy	0.91	11.46**
2. Non-renewable energy	0.31	2.92**
R^2	0.85	
RTS	1.02	

Note: * and ** indicate significance at 5% and 1% probability levels, respectively.

Model II showed that the impact of indirect and direct energy in grapefruit production were significant at a 1% probability level with 0.86 and 0.91 regression coefficients, respectively. Model III explains the significance impact for both renewable and non-renewable energy forms with 0.91 and 0.31 regression coefficients, respectively.In a study on tangerine production, econometric model on energy forms represented that all forms of energy (D, ID, RE and NRE) had significant impacts on yield (Mohammadshirazi et al., 2012). In apple production Rafiee et al. (2010) reported that direct, indirect, renewable and non-renewable energy forms had significant impact on yield with 1.48, 0.46, 0.70 and 1.31 regression coefficients, respectively.

3.5 Orchard efficiency improvement

Grapefruit trees have a long production life and if they are maintained in suitable situation an orchard economic life can extended to be 40 years. The distance between the grapefruit trees (tree density) will determine the density of the grapefruit grove. Spacing distances between trees are intended to prevent overcrowding in the orchard and also is important to expose trees to the sun light. In Sari region the main spacing pattern is 4m ×6m and in comparison with other citrus fruits changing the spacing pattern to 4×4 can increase the grapefruit yield. Adequate pruning is another important factor in grapefruit production. Pruning methods and frequencies are widely varied on mature trees and commonly can be done every year. Also hand pruning of dead wood enhances spray deposition which is particularly an important factor in grapefruit production. On the other hand, hand pruning can also increase the amount of fruit inside the tree. The marketable quality of the grapefruits depends on the stage at which they are picked. In this region, grapefruits are allowed to be left on the tree until it reaches the maximum size. It is suggestedthat the orchardists harvest the orchard based on the marketable size with at least 35% of its juice content. According to the result of the saving energy it's clear that there is a high amount of energy wastage in fertilizing. To sum it up the farmers have not enough knowledge to use proper amount of fertilizers. So new policy to use proper amount of fertilizers is needed.The grapefruits will not damage easily due to their thin protective skins, so using harvesting machines is a good solution to energy optimization. In order to get maximum yield and life, grapefruits are most commonly picked during autumn and in October. Grapefruit yields can vary depending on the grapefruit tree production, location, weather conditions, soil fertility and any other factors that can affect the fruits production, but totally good farm management is the main factor to increase the grapefruit yield. Results of this study showed that there is a great potential for improving energy of grapefruit production in the north of Iran.

4 Conclusions

Good climatic condition in Sari region induced to improve grapefruit production. In this research, an energy analysis for grapefruit production in Sari region of Iran was conducted to discriminate efficient grapefruit orchards from inefficient ones using DEA approach. Additionally, to find the relation between inputs and outputs Cobb-Douglas production function was applied. The results showed that from total of 71 orchards, based on CCR, 21 orchards and based on BCC 43 orchards were relatively efficient. The average of PTE and TE calculated as 0.86 and 0.94, respectively. The energy saving target ratio for grapefruit production was calculated as 4228.17 MJ/ha, indicating that by following the recommendations resulted from this study, about 9.2% of total input energy could be saved while holding the constant level of yield. Also, chemical fertilizers and diesel fuel had the highest amount of energy saving. On the other hand, chemical fertilizer with 0.51 impact and water for irrigation with 0.44 impacts contributed significantly to productivity at 1% probability level. Additionally, the impacts of indirect and direct energy in grapefruit production were significant at a 1% probability level with 0.84 and 0.89 regression coefficients, respectively.

Chemical fertilizer had the highest share on energy consumption for grapefruit production and by recommendations of this study it is first input that should be reduced to achieve optimum energy consumption. Also, the results of econometric model show the necessity of use of chemical fertilizers on yield level. So, the most important input in grapefruit production is chemical fertilizers and use of this input source need an adequate management to attainment economical grapefruit yield level together with lower energy consumption rate and environmental pollution.

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