INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 5, Issue 2, 2014 pp.207-218
Journal homepage: www.IJEE.IEEFoundation.org

Optimization of energy required and potential of greenhouse gas emissions reductions for nectarine production using data envelopment analysis approach

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Abstract
In this study a non-parametric method of Data Envelopment Analysis (DEA) is used to estimate the energy efficiency and greenhouse gas emissions reduction of nectarine orchard holders in Sari region of Iran. Data were collected using a face-to-face questionnaire method from 45 orchardists. The results showed that based on constant returns to scale model, 24.4% of nectarine orchards were efficient, though based on variable returns to scale model it was 26.7%. The average of technical, pure technical and scale efficiency of nectarine orchards were 0.85, 0.99 and 0.86, respectively. By following the recommendations of this study about 1309 MJ ha^{-1} (3.25%) of total input energy could be saved. From total saved energy, electricity by 24.8% had highest share, followed by diesel fuel by 22.2%, fertilizers by 16.6% and water for irrigation by 11.8%. Also, energy ratio, energy productivity and net energy gained could improve by 3.68%, 2.78% and 9.03%, respectively. The results indicated that the total GHG emission of present and optimum orchards was found to be about 1266 and 1221 $kgCO_{2eq.}ha^{-1}$, respectively. Moreover, the total GHG emissions can be reduced about 45 $kgCO_{2eq.}ha^{-1}$in nectarine production by converting inefficient units to efficient ones.

Keywords: Data envelopment analysis; Greenhouse gas emissions; Energy efficiency; Energy indices; Nectarine.

1. Introduction
Nectarines (*P. persica var. nucipersica)* are essentially the same fruit as peach, the primary difference is that nectarines are smooth-skinned and peaches are fuzzy. China, Italy, the United States of America, Spain and Greece are the main peach producers in the world respectively, followed by Iran, ranked in 6th place, also total of peach and nectarine production of Iran was about 498346 tons [1]. The energy is defined as the capacity to do work at the heart of all human activities, especially those concerning the production of goods and services [2]. The energy in agriculture is important in terms of crop production and agro processing for value adding. Human, animal and machinery are extensively used for crop production in agriculture [3]. Energy use in agricultural production has been increasing faster in comparison with many other sectors of the world economy because agricultural productions are becoming more mechanized, an increase in commercial fertilizers and other non-traditional farming

methods [4]. Intensive energy consumption as well as reducing the known energy resources is the key factor to develop the philosophy of optimum energy consumption. Optimum use of energy helps to achieve increased production and contributes to the economy, portability and competitiveness of agricultural sustainability of rural communities [5]. 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 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 [6]. The enhancement of the greenhouse effect leads to increasing Earth-surface temperatures and global climate change. Global climate change and population growth are placing new pressures on food production systems; demanding increases food security while safeguarding the natural resources by reducing the environmental footprints [7]. The reduction of energy consumption is tantamount to reduction of greenhouse gas (GHG) emissions in agricultural activity. Because both items have direct relationship with input usage in agricultural activities. Several investigations had been done on energy use optimization and GHG emissions reductions using DEA such as: Khoshnevisan et al [8] investigated the optimization of energy consumption and GHG emissions reduction for wheat production. Nabavi-Pelesaraei et al. [9] determined and compared the efficient and inefficient orange producers in terms of energy consumption and GHG emissions. They determined the effect of energy optimization on GHG emissions for converting inefficient units to efficient ones. In another study, the DEA method was applied to improve energy efficiency and GHG emissions in cucumber production [10].

With considering lack of any study on energy use efficiency and GHG emissions in nectarine production by using DEA, attempt has been made to determine the technical, pure technical and scale efficiency of nectarine orchards in Iran. Therefore, the present study was undertaken to discriminate efficient orchardists from inefficient ones and optimize the energy inputs and GHG emissions reductions on nectarine production in the Sari region of Iran.

2. Materials and methods

2.1 Sampling design

This study was conducted in the Sari Region, in the north of Iran within 35° 58 and 36° 50 north latitude and 52° 56 and 53° 59 east longitudes [11].The surveyed region had homogenous conditions for orchard establishment with regards to climatic conditions, topography and soil type. The initial data were collected from nectarine orchardists using face-to-face questionnaire in the production year 2012/2013.The sample size was determined by simple random sampling method [12]. Accordingly, the sample size was calculated as 39. In order to increase the accuracy, the sample was considered 45 in this study. It’s should be noted, all of the orchards were single-crop nectarine orchards.

2.2 Energy equivalents of inputs and output

Nectarine is an important agricultural commodity in sari region. Very well-drained soils, abundant nitrogen fertility, plenty of summer water, fruit thinning, and pest control sprays to prevent peach leaf curl and brown rot are major requirements for nectarine orchards. Nectarines orchards required energy input from seven sources include human power, machinery, diesel fuel, pesticides, chemical fertilizers, water for irrigation and electricity. Also, nectarine yield is the only energy output. In order to calculate the amount of energy used by each orchardist, each input source was converted into its energy equivalent so the information of Table 1 is used. The input and output were calculated per hectare for each orchard and then these data were multiplied by the coefficient of energy equivalent (Table 1). As can be seen in Table 1, the total energy consumption and nectarine yield were calculated about 40275 MJ ha^{-1} and 54851 kg ha^{-1}, respectively.

2.3 Data envelopment analysis (DEA)

DEA was first introduced as a general method for classifying a population of observations and was designed as a decision support tool for complex systems, where a large number of mutual interacting variables are involved [22]. 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 termedDMUs in DEA terminology. In this study two main model of DEA include: CCR (Charnes-Cooper–Rhodes) and BCC (Banker-Charnes-Cooper) were used. The CCR model is built on the assumption of constant returns to scale (CRS) of activities and the BCC model is built on the assumption of variable returns to scale (VRS) of activities[23]. Also, the efficiency of orchards was discussed based on different forms of DEA includes: Technical Efficiency (TE), Pure Technical Efficiency (PTE) and Scale Efficiency (SE). The input variables were defined as: human power, machinery, pesticides, water for irrigation, electricity, chemical fertilizers and diesel fuel, while, the nectarine yield was the single output variable.

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

Inputs (unit)	Energy equivalent (MJ unit^{-1})	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})
A. Inputs			
1. Human labor (h)	1.96 [13]	1339	2624
2. Machinery (h)	62.7 [9]	61.5	3855
3. Diesel fuel (l)	56.3 [14]	141	7929
4. Chemical fertilizers (kg)			
(a) Nitrogen	66.1 [15]	147	9800
(b) Phosphate (P_2O_5)	12.4 [16]	98.1	1220
(c) Potassium (K_2O)	11.1 [17]	175	1957
(d) Sulphur (S)	1.1 [15]	89.3	100
5. Farmyard manure (kg)	0.3 [18]	6000	1800
6. Pesticides (kg)			
(a) Insecticide	101.2[19]	8.23	834
(b) Herbicide	238[19]	2.10	500
(c) Fungicide	92 [20]	9.78	900
7. Water for irrigation (m^3)	1.1[18]	3676	3749
8. Electricity (kWh)	11.9 [18]	420	5007
The total energy input (MJ)			40275
B. Output			
1. Nectarine (kg)	1.9 [21]	28869	54851

2.4 Technical efficiency

Technical efficiency (global efficiency) is basically a measure by which DMUs are evaluated for their performance relative to the performance of other DMUs in consideration. The technical efficiency can be defined as follows (Eq. 5) [24, 25].

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

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 Eq. (1), following Linear Programming (LP) was formulated:

$$Maximize\ \theta = \sum_{r=1}^{n} u_r y_{rj}$$

$$Subjected\ to\ \sum_{r=1}^{n} u_r y_{rj} - \sum_{s=1}^{m} v_s x_{sj} \le 0 \quad (2)$$

$$\sum_{s=1}^{m} v_s x_{sj} = 1$$

$$u_r \geq 0,\ v_s \geq 0,\ \textit{and (i and j= 1, 2, 3, ..., k)}$$

where θ is the technical efficiency, Model (3) is known as the input oriented CCR DEA model assumes constant returns to scale (CRS) [26].

2.5 Pure technical efficiency

This model called BCC 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 orchards are only compared to efficient orchards of a similar size [27]. The dual model is derived by construction from the standard inequality form of linear programming [28]. It can be expressed by Dual Linear Program (DLP) as follows [15]:

$$\begin{aligned} &\textit{Maximize} \quad z = uy_i - u_i \\ &\textit{Subjected to} \quad vx_i = 1 \\ &-vX + uY - u_o e \leq 0 \\ &v \geq 0,\ u \geq 0 \ \textit{ and } \ u_o \ \textit{ free in sing} \end{aligned} \tag{3}$$

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 the corresponding output and input matrixes, respectively. The letters x_i and y_i refer to the inputs and output of its DMU.

2.6 Scale efficiency

Scale efficiency gives quantitative information of scale characteristics; it is the potential productivity gain from achieving optimal size of a DMU. The relationship among the scale efficiency (SE), technical efficiency (TE) and pure technical efficiency (PTE) can be expressed as follows [29]:

$$\textit{Scale efficiency} = \frac{\textit{Technical efficiency}}{\textit{Pure technical efficiency}} \tag{4}$$

Using scale efficiency 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) [30]. If an orchard is fully efficient in both the technical and pure technical efficiency scores, it is operating at the most productive scale size. On the other hand if an orchard has the high 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 [31]. 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 Eq. (5):

$$ESTR_j = \frac{(Energy\ Saving\ T\arg et)_j}{(Actual\ Energy\ Input)_j} \tag{5}$$

2.7 GHG emissions

Application of these inputs leads to emission of CO_2 and other GHGs. Thus, an understanding of the emissions expressed in kg CE (kilograms of carbon equivalent) for different tillage operations, chemical fertilizers and pesticides use, supplemental irrigation practices, harvesting and residue management is essential to identifying C-efficient alternatives such as biofuels and renewable energy sources for seedbed preparation, soil fertility management, pest control and other orchard operations [8, 32]The GHG emissions of nectarine production were computed by standard coefficient of CO_2 emissions for each input (Table 2). The inputs were reasonable of GHG emissions in nectarine production including diesel fuel, machinery, electricity, chemical fertilizers and pesticides. After determination of efficient and inefficient units, the GHG emissions was calculated for optimal condition and compared with regular condition. The purpose of this research was determination of GHG reductions using DEA.

Table 2. GHG emissions coefficients of agricultural inputs

Input	Unit	GHG Coefficient (kg CO_{2eq} unit^{-1})	Reference
1. Machinery	MJ	0.071	[33]
2. Diesel fuel	L	2.76	[34]
3. Chemical fertilizers			
(a) Nitrogen	kg	1.3	[10]
(b) Phosphate (P_2O_5)	kg	0.2	[9]
(c) Potassium (K_2O)	kg	0.2	[35]
4. Pesticides			
(a) Insecticide	kg	6.3	[32]
(b) Herbicide	kg	5.1	[32]
(c) Fungicide	kg	3.9	[32]
5. Electricity	kW h	0.608	[9]

Basic information on energy inputs of nectarine production were entered into Excel 2013 spreadsheets, and Frontier Analyst 4 software programs.

3. Results and discussion

3.1 Efficiency estimation of orchardists

The results of BCC and CCR models of DEA showed that from total of 45 orchardists, based on CCR results, only 11 orchards were relatively efficient and their efficiency score were 1. Also, from the results of BCC model 29 orchards were efficient. The average of pure technical efficiency and technical efficiency calculated as 0.853 and 0.987, respectively. Moreover, the pure technical efficiency varied from 0.88 to 1. Also, the minimum amount of the technical efficiency was calculated as 0.55.Mousavi-Avval et al. [29] applied the non-parametric method of DEA to determine the technical and pure technical efficiencies of orchardists for apple production in Iran; they found that TE and PTE were 0.79 and 0.90, respectively. Nabavi-Pelesaraei et al. [9] was computed average of TE, PTE and SE of about for orange orchardists by DEA method, respectively. In another study on alfalfa production, TE, PTE and SE of farmers were calculated as 0.84, 0.97 and 0.89, respectively [23]. The summarized statistics for the three estimated measures of efficiency are presented in Table 3. The wide range in the technical efficiency 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 [6].Additionally, the calculation of scale efficiency shows that this amount was measured as 0.86, implying that the average size of farms was in optimal size.

Table 3. Average technical, pure and scale efficiency of nectarine orchardists (45 units)

Particular	Average	SD	Min	Max
Technical efficiency	0.853	0.142	0.55	1
Pure technical efficiency	0.987	0.026	0.88	1
Scale efficiency	0.865	0.143	0.55	1

Results obtained by the application of the input-orientated BCC and CCR models are illustrated in Figure 1. 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. The result showed that 12 orchard were Efficient. Also, 12 orchards were between 0.9 to < 0.99, 14 orchards were between 0.7 to < 0.89 and 7 remain orchard had the efficiency between 0.5 and 0.69.

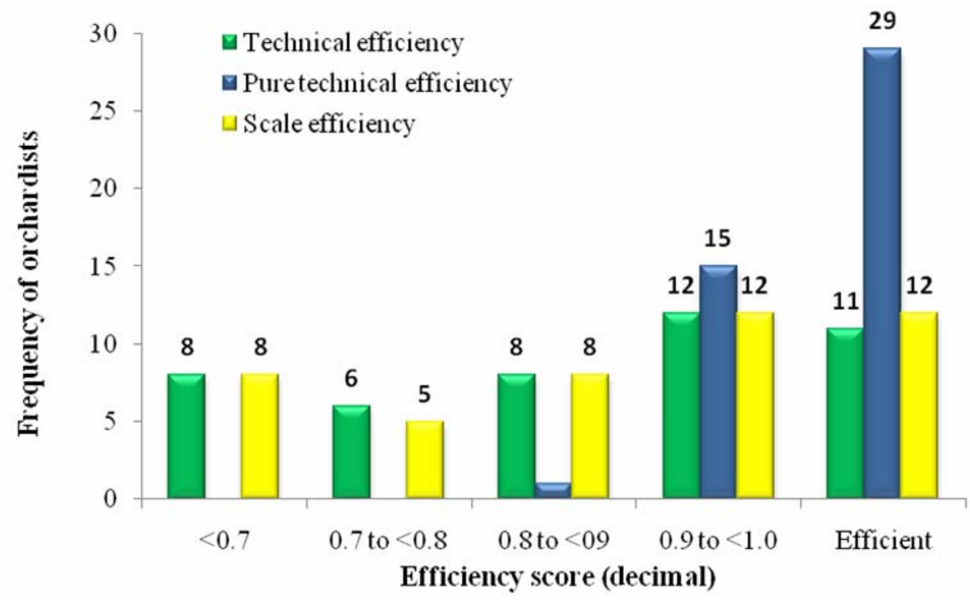

Figure 1. Efficiency score distribution of nectarine producers

3.2 Optimum energy requirement and saving energy

The optimum energy requirement and saving energy for nectarine production based on the results of BCC model is shown in Table 4.The total energy saving was computed as 1309 MJ ha^{-1}. From Table 4 it is clear that, the highest saving energy is provided by electricity (325MJ ha^{-1}) energy inputs, followed by diesel fuel (291 MJ ha^{-1}) and chemical fertilizers (217 MJ ha^{-1}). Savings energy in the different sources is possible by change in production procedure. For example many orchardists used pesticides to control herbs. Plowing the soil with disk harrow or moldboard plow instead of chemical agents can be a useful way to control herbs.

Table 4. Optimum energy requirement and saving energy for nectarine production

Input	Optimum energy requirement (MJ ha^{-1})	Saving energy (MJ ha^{-1})	Saving energy (%)	Contribution to the total savings energy (%)
1. Human labor	2523	101	3.85	7.72
2. Machinery	3783	72	1.87	5.50
3. Diesel fuel	7638	291	3.67	22.2
4. Chemical fertilizers	12860	217	1.66	16.6
5. Farmyard manure	1754	46	2.56	3.51
6. Pesticides	2132	102	4.57	7.79
7. Water for irrigation	3595	154	4.11	11.8
8. Electricity	4682	325	6.49	24.8
Total energy	38966	1309	3.25	100

As can be seen in Table 4, that the highest contribution to the total savings energybelonged to electricity with 24.8%, followed by diesel fuel with 22.2% and chemical fertilizers with 16.6%.The inappropriate electro pumps for irrigation were the main reason forindiscriminate use of electricity. Also, the non-standard machinery was effective in excessive consumption of diesel fuel and availability of chemical fertilizers (specially nitrogen) was the reason for high consumption of chemical fertilizers in the studied area. Accordingly, the selection of appropriate electro pumps, imports of standard machinery, timely maintenance and reduction of chemical fertilizers (mainly nitrogen).

3.3 Improvements of energy indices

Energy indices such as energy ratio, energy productivity, and net energy gain, as well as the distribution of sources according to direct, indirect, renewable and non-renewable energy groups are given in Table 5.

Table 5. Improvement of energy indices for nectarine production

Items	Unit	Present quantity	Optimum quantity	Difference (%)
Energy use	–	1.36	1.41	3.68
Energy productivity	kg MJ^{-1}	0.72	0.74	2.78
Specific energy	MJ kg^{-1}	1.40	1.35	-3.57
Net energy	MJ ha^{-1}	14569	15884	9.03
Direct energy[a]	MJ ha^{-1}	19309 (47.9%)[e]	18438 (47.3%)	-4.51
Indirect energy[b]	MJ ha^{-1}	20966 (52.1%)	20528 (52.7%)	-2.09
Renewable energy[c]	MJ ha^{-1}	8173 (20.3%)	7872 (20.2%)	-3.68
Non–renewable	MJ ha^{-1}	32102 (79.7%)	31094 (79.8%)	-3.14
Total energy input	MJ ha^{-1}	40275 (100%)	38966 (100%)	-3.25

[e]Numbers in parentheses indicate percentage of total optimum energy requirement.

[a] Includes human labor, diesel fuel, water for irrigation, electricity.

[b] Includes chemical fertilizers, farmyard manure, pesticides, machinery.

[c] Includes human labor, farmyard manure, water for irrigation.

[d] Includes diesel fuel, electricity, pesticides , chemical fertilizers, machinery.

The results showed that energy use efficiency (energy ratio) can be improved to the value of 1.41 by increasing 3.68%. Also energy productivity, specific energy and net energy in target situation were found to be 0.74 kg MJ^{-1}, 1.35 MJ kg^{-1} and 15884 MJ ha^{-1}, that indicates improving of this indices about 2.78%, -3.57% and -9.03%, respectively. In similar study on kiwifruit production the results showed that energy use efficiency and net energy could be improved by 13.86% and 22.56%, respectively, if the farmers applied the recommendations of study results [6]. Pahlavan et al. [36] in the study on rose production showed that energy use efficiency and net energy could improve by 77.29% and 52.73%, respectively.

3.4 Setting realistic input levels for inefficient orchardists

In Table 6 the pure technical efficiency, actual energy use and suggested energy requirement from different energy sources for individual inefficient nectarine orchards shown. Also, their average and standard deviation values are presented. The values of optimal energy requirement are the recommendations resulted from this study, indicating how individual inefficient production units can reduce their source wise energy inputs by holding the output level constant. In the last column of Table 6 the ESTR percentage for inefficient orchards are given. As it can be seen, for inefficient production units, ESTR ranges from 0% to 14.9% (orchard no. 14), with the average of 4.13%, indicating that between inefficient production units, the units that have near to zero value of ESTR had better management on input usage, and the no.14 unit was the most inefficient one.

3.5 Reduction of GHG emission

The amount of GHG emissions for present and optimum units is given in Table 7. The total GHG emissions of present and optimum orchardists were calculated as 1266 and 1221 $kgCO_{2eq.}ha^{-1}$, respectively. Accordingly, the total GHG emissions can be reduced about 45 using energy optimization by DEA. So, it can be said the energy consumption had a direct relationship with GHG emissions. In a similar study, Khoshnevisan et al., [8] reported the energy optimization by DEA would be decreased total GHG emissions of wheat production about 40.3 $kgCO_{2eq.}ha^{-1}$by approach. In another study, Nabavi-Pelesaraei et al. [9] applied DEA approach to determination of GHG emissions for efficient and inefficient orange orchardists. They reportedthe different of GHG emissions between efficient and inefficient units was about 184 $kgCO_{2eq.}ha^{-1}$.

Figure 2 displays the share of each input in potential of total GHG reduction in nectarine production. The results illustrated the electricity with 35.6% had the highest share in GHG emissions reduction, followed by diesel fuel with 33.3% and machinery with 11.1%. As can be deduced from the results, it’s suggested, the appropriate electro pumps, standard machinery and timely maintenance was applied for nectarine production in studied area.

Table 6. The source wise actual and target energy use for inefficient orchardists in the nectarine production (based on BCC Model)

DMU	PTE *	Actual energy use (MJ ha^{-1})								Optimum energy requirement (MJ ha^{-1})								ESTR (%)
		Water	Human labor	Machinery	Electricity	Chemical fertilizers	Diesel fuel	Pesticides	Farmyard manure	Water	Human labor	Machinery	Electricity	Chemical fertilizers	Diesel fuel	Pesticides	Farmyard manure	
2	1.00	5470	2300	3420	6840	12584	7100	2300	1716	5470	2300	3420	6840	12584	7100	2300	1716	0.0
4	0.99	5400	2870	3400	3690	12320	8100	2580	1680	3850	2457	3357	3644	12165	7169	2262	1659	8.7
5	1.00	3800	1890	3590	4400	12619	7400	1490	1721	3800	1890	3590	4400	12619	7400	1490	1721	0.0
6	1.00	4200	2100	3160	5780	12170	7500	2100	1660	4200	2100	3160	5780	12170	7500	2100	1660	0.0
9	0.92	3100	3200	3990	5680	13842	7280	2750	1888	2860	2952	3681	4701	12771	6717	2106	1742	10.1
10	1.00	3900	2940	4320	4580	12716	7900	2340	1734	3902	2941	4322	4582	12721	7903	2341	1735	0.0
11	0.98	4900	2640	4990	6540	14168	8100	2340	1932	4108	2575	4767	4550	13818	7900	2282	1884	8.2
13	0.93	3800	2380	4560	4565	13534	9400	2380	1846	3517	2203	4220	3895	12525	7675	2203	1708	10.6
14	0.88	4200	2660	3900	5875	13904	8500	2460	1896	3675	2328	3413	4453	12166	7237	2016	1659	14.9
15	0.99	3350	2260	3960	5265	12628	9049	2360	1722	3310	2233	3912	4028	12475	7515	2065	1701	8.3
16	0.97	4000	2340	3560	4580	12584	10000	2340	1716	3730	2271	3454	4444	12210	7271	1954	1665	10.0
17	1.00	2800	3440	3220	5680	13200	7100	1990	1800	2800	3440	3220	5680	13200	7100	1990	1800	0.0
19	0.98	3140	3000	2980	6000	11000	6550	2460	1500	3062	2764	2906	4372	10513	6388	2026	1434	8.6
20	0.99	4300	2050	3560	4600	13702	8000	1890	1868	3541	2039	3541	4392	13051	7542	1817	1780	5.7
22	1.00	3750	2460	3050	6480	13156	8570	1560	1794	3750	2460	3050	6480	13156	8570	1560	1794	0.0
23	1.00	3800	2150	3990	3560	13006	6600	1850	1774	3800	2150	3990	3560	13006	6600	1850	1774	0.0
24	1.00	2900	2830	2900	3780	9680	6500	1900	1320	2900	2830	2900	3780	9680	6500	1900	1320	0.0
28	1.00	2400	2100	4100	4695	13244	7850	2600	1806	2400	2100	4100	4695	13244	7850	2600	1806	0.0
29	1.00	3400	2140	3940	3540	13816	8350	2140	1884	3400	2140	3940	3540	13816	8350	2140	1884	0.0
30	0.99	3600	2900	3485	5360	12584	9200	2360	1716	3558	2591	3444	4597	12436	7529	2168	1696	7.7
31	0.95	4300	3500	4990	6190	15312	8950	2900	2088	4088	2725	4744	5015	14087	8508	2369	1921	9.9
32	1.00	3600	2340	2980	4360	11176	6700	2650	1524	3600	2340	2980	4360	11176	6700	2650	1524	0.0
33	0.99	3750	2340	3990	3590	13622	7900	2340	1858	3694	2312	3943	3548	13374	7807	2054	1824	2.1
34	1.00	4100	1930	3550	6500	13992	6850	1630	1908	4100	1930	3550	6500	13992	6850	1630	1908	0.0
35	1.00	3260	2380	3060	6100	13376	8040	2380	1824	3260	2380	3060	6100	13376	8040	2380	1824	0.0
36	1.00	2700	2900	2900	3780	11528	7080	2460	1572	2700	2900	2900	3780	11528	7080	2460	1572	0.0
37	0.98	3600	3360	3940	5230	14520	7896	2360	1980	3225	2484	3847	3949	13806	7710	2305	1883	8.6
38	0.94	4200	2850	4450	4900	14344	8280	2340	1956	3691	2595	4204	4438	13549	7821	2210	1848	6.8
39	0.98	4100	3700	3900	6800	11704	5900	1890	1596	3039	2844	3179	4447	11476	5785	1853	1565	13.6
40	1.00	3700	2050	4800	3690	12302	7650	2350	1678	3700	2050	4800	3690	12302	7650	2350	1678	0.0
41	1.00	3900	2400	2800	6545	12408	7200	2670	1692	3900	2400	2800	6545	12408	7200	2670	1692	0.0
43	1.00	2890	2860	3050	4695	12232	5000	1900	1668	2890	2860	3050	4695	12232	5000	1900	1668	0.0
44	0.96	3600	2980	4500	4695	15356	9300	2860	2094	3446	2659	4308	4495	14242	8903	2337	1942	6.7
45	1.00	4000	2150	2950	3695	12056	6600	2550	1644	4000	2150	2950	3695	12056	6600	2550	1644	0.0
Ave.	**0.98**	**3762**	**2600**	**3704**	**5067**	**12953**	**7717**	**2278**	**1766**	**3558**	**2452**	**3609**	**4637.3**	**12645**	**7337.3**	**2143.7**	**1724**	**24.8**
S.D.	**0.03**	**682**	**485**	**635**	**1072**	**1199**	**1077**	**354**	**164**	**565**	**351**	**582**	**948.3**	**1007**	**788.9**	**294.4**	**137**	**20.0**

Table 7. Amounts of GHG emission for presentand target orchardists

Input	Presentorchardists (kg $CO_{2eq.}$ ha^{-1})	Targetorchardists (kg $CO_{2eq.}$ ha^{-1})	GHG reduction (kg $CO_{2eq.}$ ha^{-1})
1. Machinery	274	269	5
2. Diesel fuel	389	374	15
3. Chemical fertilizers			
(a) Nitrogen	193	189	4
(b) Phosphate (P_2O_5)	19.6	19.3	0.3
(c) Potassium (K_2O)	35.1	34.5	0.6
4. Pesticides			
(a) Insecticide	51.9	49.5	2.4
(b) Herbicide	10.7	10.2	0.5
(c) Fungicide	38.2	36.4	1.8
5. Electricity	255	239	16
Total GHG emissions	1266	1221	45

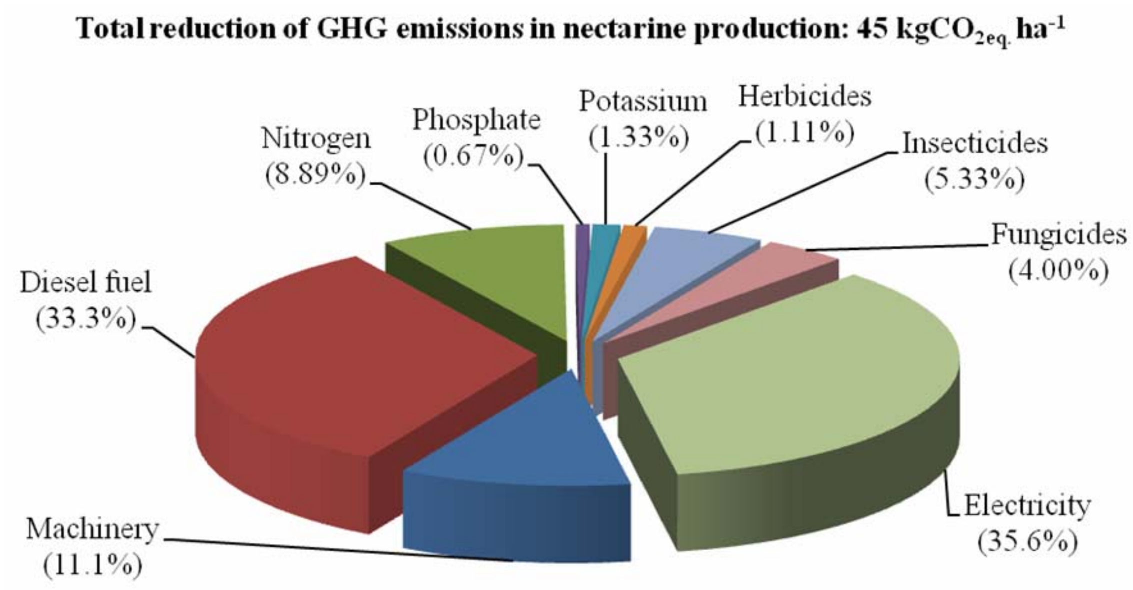

Figure 2. The share of each input for GHG emission reduction of nectarine production

4. Conclusions

Like most stone fruits, nectarines thrive in a Mediterranean climate of long, hot summers and cool, wet winters. Good climatic condition in Sari region induced to improve nectarine production in recent years. In this research, an energy analysis for nectarine production in Sari region of Iran was conducted to discriminate efficient nectarine orchards from inefficient and GHG emissions reduction using DEA approach. Based on study results, following conclusions were drawn:

1. From the total of 45 nectarine orchards considered for the analysis, 24% and 27% were found to be technically and pure technically efficient, respectively.
2. The average values of technical, pure technical and scale efficiency scores of orchards were found to be 0.85, 0.99 and 0.87, respectively.
3. The energy saving target ratio for nectarine production was calculated as 1309 MJ ha^{-1}, indicating that by following the recommendations resulted from this study, about 3.25% of total input energy could be saved while holding the constant level of yield. Also the electricity energy has highest potential for improvement by 6.49%. Also from total saved energy electricity had highest share by 24.8%.
4. By optimization of energy consumption, the energy ratio, energy productivity, specific energy and net energy can improved with 3.68%, 2.78%, -3.57% and 9.03%, respectively.

ISSN 2076-2895 (Print), ISSN 2076-2909 (Online)

5. The GHG emission of present and optimum units was found to be as 1266 and 1221 $kgCO_{2eq}.ha^{-1}$, respectively. The potential of GHG reduction was calculated about 45 $kgCO_{2eq}.ha^{-1}$. Also, the highest share of potential of GHG reduction was belonged to electricity in nectarine production. According to the recommendations of this study, optimization of energy inputs can reduce GHG emission in agricultural systems, significantly.

Acknowledgment
The financial support provided by the Khuzestan Ramin Agricultural and Natural Resources University, Iran, is duly acknowledged. Also, I want to express my deep appreciation of all Mr. Kamran Taromi's efforts to help me revise the study.

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