Application of nonparametric method to improve energy productivity and CO_2 emission for barley production in Iran

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Abstract: The nonparametric method of data envelopment analysis (DEA) was used to investigate the energy efficiency and CO_2 emission of barley farm in Hamedan province of Iran. The method was used based on eight energy inputs including human labor, machinery, diesel fuel, fertilizers, farmyard manure, biocide, electricity and seed energy and single output of barley yield and technical, pure technical, scale and cross efficiencies were calculated using CCR and BCC models. The results showed that the average values of technical, pure technical and scale efficiency scores of farmers were 0.788, 0.941 and 0.833, respectively. Also, energy saving target ratio for barley production was calculated as 11.45%, indicating that by following the recommendations of this study, about 2,865 MJ ha^{-1} of total input energy could be saved with the same constant level of barley yield. Moreover the contribution of chemical fertilizer input from total saving energy was 34.88% which was the highest share followed by diesel fuel (25.88%) and electricity (20.89%) energy inputs. On one hand, optimization of energy use improved the energy use efficiency, energy productivity and net energy by 12.94%, 15.55% and 6.16%, respectively. On the other hand, total greenhouse gases (GHG) emission was 885.56 kg CO_{2eq} ha^{-1}, which indicated that, the total CO_2 emissions can be reduced by 11.06%.

Keywords: data envelopment analysis, energy saving, barley, chemical fertilizers

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1 Introduction

Barley is a common staple in human and animal diets. Part of the grass family, barley grows in over 100 countries and is one of the most popular cereal crops, surpassed only by wheat, corn and rice. Although barley is fairly adaptable and can be grown in many regions, it is a tender grain and care must be taken in all stages of its growth and harvest. Barley serves as a major animal fodder and as a component of various health foods. It is used in soups and stews. Barley is one of the major crops grown in the Hamedan province and is grown once a year during the spring season. In Hamedan province barley is established in autumn (September and early October) and it is harvested in the late spring (early June). The average barley yield in this state is about 4,850 kg ha^{-1} (Mobtaker et al., 2010).

Energy is one of the most valuable inputs in agricultural production. It is invested in various forms such as mechanical, electrical, chemical, thermal, nuclear and radiation. Production, storage, distribution and

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application of inputs which used in agriculture lead to combustion of fossil fuel, and use of energy from alternate sources, which also emits CO_2 and other greenhouse gases (GHGs) into the atmosphere (Lal, 2004). The amount of energy used in agricultural production, processing and distribution needs to be adequate in order to feed the rising population and to meet other social, environmental and economic goals. Efficient use of input energy contributes to the profitability and competitiveness of agriculture (Singh et al., 2002).

There are a lot of tools and multiple criteria decision models used for evaluation of manufacturing and service systems. These are multi–attribute utility theory, expert systems, mathematical programming, analytical hierarchy process outranking, simulation and scoring models (Onut and Soner, 2007). Data envelopment analysis is one of them. The DEA is an analysis method to measure the relative efficiency of a homogeneous number of production units or decision–making units (DMU) that essentially perform the same tasks. It results in a revealed understanding about each DMU instead of depicting the features of a mythical ‘‘average’’ DMU as in parametric analysis (Chauhan et al., 2006).

In the DEA literature, there are basically two kinds of DEA models. These are CCR (Charnes, Cooper and Rhodes) and BCC (Banker, Charnes, Cooper) models. The CCR model is built on the assumption of constant returns to scale of activities and measures the technical efficiency by which the DMUs are evaluated for their performance relative to other DMUs in a sample. But the BCC model is built on the assumption of variable returns to scale of activities. Therefore this model calculates the technical efficiencies of DMUs under variable return to scale conditions (Onut and Soner, 2007; Mousavi-Avval et al., 2011). Considerable studies have been conducted on energy use and optimization of energy required for agricultural production (Pishgar–Komleh et al., 2012; Taki et al., 2012; Tabatabaie et al., 2013; Taki et al., 2013). In the research conducted in India, a data envelopment analysis approach was used to determine the efficiencies in rice production farms. The results revealed that, on an average, about 11.6% of the total input energy could be saved if the farmers followed the input package recommended by the study. The study also suggested that better use of power tillers and introduction of improved machinery would improve the efficiency of energy use and thereby improve the energy productivity of the rice production system in the zone (Chauhan et al., 2006). Nassiri and Singh (2009) applied non–parametric method data envelopment analysis (DEA) technique to determine the efficiencies of farmers with regard to energy use in paddy producers in Punjab state (India) and calculated technical, pure technical and scale efficiencies (defined in materials and methods) for farmers category–wise and zone–wise using CCR and BCC models. Results revealed that small farmers had high energy–ratio and low specific energy requirement as compared to larger ones at paddy farms. Although there was high correlation between technical efficiency and energy–ratio, comparison between correlation coefficient of farmers in different farm categories and different zones showed that energy–ratio and specific energy were not enhanced indices for explaining of all kinds of the technical, pure technical and scale efficiency of farmers. Mousavi–Avval et al. (2011) employed the DEA technique to estimate the energy efficiencies of soybean producers in Golestan province of Iran. They reported the technical, pure technical and scale efficiencies of farmers were 0.853, 0.919 and 0.926, respectively. Also the results indicated that by following the recommendations of the study, about 7,116.84 MJ ha^{-1} of total input energy could be saved while holding soybean yield constant. Pahlavan et al. (2012) used DEA approach to analyze the energy efficiency of rose production in Iran. The results revealed that the average pure technical, technical and scale efficiencies of farmers were 0.83, 0.68 and 0.79, respectively. Moreover by optimization of energy consumption in rose production energy use efficiency was increased from 0.17 to 0.31. Also, the results revealed that by adopting the recommendations based on the study, on an average, about 43.59% of the total input energy could be saved without reducing the rose yield. In another study Mobtaker et al. (2012) reported that by optimization of energy inputs in alfalfa production, the total CO_2 emissions in alfalfa production can be reduced by 5.62%.

The objectives of this study were to specify energy use patterns, identify target energy requirements and wasteful uses of energy from different inputs for barley production in Hamedan province of Iran. Also the amount of total CO_2 emissions in barley production in present and target condition was investigated using CO_2 emission coefficient of agricultural inputs.

2 Materials and methods

The research was carried out in Hamedan province which is located in the west of Iran; within 33°59′ and 35°48′ north latitude and 47°34′ and 49°36′ east longitude. The long-term (30 years) average precipitation is 323 mm. The temperature of region range between -33°C to 40°C and its average is approximately 11°C (Anonymous, 2013). In this research the DEA approach was used to analyze the data for optimizing the performance measure of each production unit or each barley farm. The data used in this study, has been collected form 67 barley farms in Hamedan province and their results in the field of energy use and sensitivity analysis of energy inputs for barley production, have been published by the authors previously (Mobtaker et al., 2010). A simple random sampling method was used to determine survey volume and the farms were chosen randomly from study region. The data included amount of inputs used in barley production such as human labor, machinery, diesel fuel, total fertilizers, biocide, electricity (for irrigation) and seeds, and the yield as an output. The inputs and output were transformed to energy term by multiplying their quantity per unit area by the coefficient of energy equivalent. For this propose the energy coefficient of previous study was used (Table 1). The inputs energy equivalents used in barley production with output energy rates are shown in Table 2. As can be seen from Table 2, there was a wide variation in the quantity of energy inputs and output for barley production; indicating that there was a great scope for optimization of energy usage and improving the efficiency of energy consumption for barley production in the region.

Table 1 Energy equivalent of inputs and output in agricultural production (Mobtaker et al., 2010)

Item	Unit	Energy equivalent/MJ unit^{-1}
A. Inputs		
1. Human labor	h	1.96
2. Machinery	h	62.70
3. Diesel fuel	l	56.31
4. Chemical fertilizers		
(a) Nitrogen	kg	66.14
(b) Phosphate (P_2O_5)	kg	12.44
5. Farmyard manure	kg	0.30
6. Biocide	kg	120
7. Electricity	kWh	11.93
8. Seed	kg	14.7
B. Output		
1. Barley	kg	14.7

Table 2 Amounts of energy inputs and output in barley production

Item	Total energy equivalent/MJ ha^{-1}	SD	Max	Min
Inputs				
1. Human labor	163.21	33.09	248.92	116.62
2. Machinery	1142.39	246.20	2100.45	721.05
3. Diesel fuel	5863.56	1193.39	9516.39	3913.55
4. Total fertilizers	6935.36	3755.98	22385.96	2354.17
5. Biocides	183.60	123.92	480.00	60.00
6. Electricity	7538.28	1502.79	12315.80	4256.57
7. Seeds	3201.07	706.30	4851.00	1911.00
Total energy input	25027.47	6145.48	43103.34	16235.71
Output				
1. Barley	71525.37	29637.97	147000.00	44100.00

As mentioned, there are basically two kinds of DEA models. The CCR DAE model which was developed by Charnes et al. (1978), assumes constant returns to scale. The efficiency score (*Technical efficiency*) is defined as Equation (1) (Mohammadi et al., 2011; Omid et al., 2011):

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

where, x and y, are input and output and v and u, are input and output weights, respectively; s, is number of inputs (s = 1,2,...,m); r, is number of outputs (r = 1,2,..,n) and j, represents jth of DMUs (j = 1,2,. . ., k).

The value of technical efficiency varied between zero and one; where a value of one implied that the DMU was a best performer located on the production frontier and had no reduction potential. Any value of TE lower than one indicated that the DMU used inputs inefficiently (Nassiri and Singh, 2009; Mousavi–Avval et al., 2012).

To solve Equation (1), Linear Programming (LP) was used (Charnes et al., 1978) according to following Equations (2), (3), (4) and (5):

$$Maximize \qquad q = \sum_{r=1}^{n} u_r y_{rj} \tag{2}$$

$$Subjected\ to \quad \sum_{r=1}^{n} u_r y_{rj} - \sum_{s=1}^{m} v_s x_{sj} \le 0 \tag{3}$$

$$\sum_{s=1}^{m} v_s x_{sj} = 1 \tag{4}$$

$$u_r \ge 0, \quad v_s \ge 0, \quad \text{and } (i \text{ and } j = 1, 2, 3, \ldots, k) \tag{5}$$

where, θ is the technical efficiency and i represents ith DMU (it will be fixed in Equations (2) and (4) while j increases in Equation (3)).

The above model assumed that there was no significant relationship between the scale of operations and efficiency (Avkiran, 2001).

The BCC was another model in DEA that introduced by Banker et al. (1984). This model calculated the technical efficiency of DMUs under variable return to scale conditions and known as pure technical efficiency. Pure Technical efficiency cou separate both technical and scale efficiencies. The main advantage of this model was that scale inefficient farms were only compared to efficient farms of a similar size (Bames, 2006). It can be expressed by Dual Linear Program (DLP) as following Equations (6), (7), (8) and (9) (Mousavi–Avval et al., 2012):

$$Maximize \qquad z = uy_i - u_i \tag{6}$$

$$Subjected\ to \qquad vx_i = 1 \tag{7}$$

$$-vX + uY - u_o e \le 0 \tag{8}$$

$$v \ge 0, u \ge 0 \quad \text{and} \quad u_o \quad free\ in\ sing \tag{9}$$

where, z and u_o are scalar and free in sign (it can be positive or negative). u and v are output and inputs weight matrixes, and Y and X are corresponding output and input matrixes, respectively. The letters x_i and y_i refer to the inputs and output of ith DMU.

Scale efficiency showed the effect of DMU size on efficiency of system. Simply, it indicated that some part of inefficiency refered 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). The relationship among the scale efficiency, technical efficiency and pure technical efficiency can be expressed as (Chauhan et al., 2006):

$$Scale\ efficiency = \frac{Technical\ efficiency}{Pure\ technical\ efficiency} \tag{10}$$

The results of standard DEA models separated the DMUs into two sets of efficient and inefficient ones; so many units were calculated as efficient and can not to be ranked. Also in DEA because of the unrestricted weight flexibility problem, it was possible that some of the efficient units were better overall performers than the other efficient ones (Adler et al., 2002). To overcome this problem and achieve a complete ranking of efficient farmers, the cross–efficiency ranking method was used which developed by Sexton et al. (1986). In this method the results of all the DEA efficiency scores can be aggregated in a matrix, called cross–efficiency matrix. In this matrix E_{ij}, the element in the ith row and jth column, represented the efficiency score for the jth farmer calculated using the optimal weights of the ith farmer which was computed by the CCR model. In general, the efficient farmers can be ranked according to their average cross efficiency score which can be achieved by averaging each column of cross–efficiency matrix and it was a matter of judgment for analysis to select the highly ranked farmers as truly efficient ones; so, a farmer with a high average cross efficiency score was a good performer (Angulo–Meza and Lins, 2002; Chauhan et al., 2006; Zhang et al., 2009).

In the analysis of efficient and inefficient DMUs the energy saving target ratio (ESTR) index was used which represents the inefficiency level for each DMU with respect to energy use. The formula is as follows (Hu, and Kao, 2007):

$$ESTR_j = \frac{(Energy\ Saving\ T\arg et)_j}{(Actual\ Energy\ Input)_j} \tag{11}$$

where energy saving target is the total amount of input that could be saved without decreasing output level and j represents jth DMU.

In the last part of study the amounts of CO_2 emission from application of different energy inputs in barley production were calculated in present condition and compared with amount of CO_2 emission in target condition. For this purpose the CO_2 emission coefficient of agricultural inputs was used. These coefficients and their references are shown in Table 3. The amount of produced CO_2 was calculated by multiplying the input application rate by its corresponding emission coefficient.

Table 3 Greenhouse gas (GHG) emission coefficients of agricultural inputs

Inputs	Unit	GHG Coefficient (kg CO_{2eq} $unit^{-1}$)	Reference
Machinery	MJ	0.071	Dyer and Desjardins, 2006
Diesel fuel	L	2.76	Dyer and Desjardins, 2006
Chemical fertilizers	kg		
(a) Nitrogen	kg	1.3	Lal, 2004
(b) Phosphate	kg	0.2	Lal, 2004
(c) Potassium	kg	0.2	Lal, 2004
Pesticides	kg		
(a) Herbicide	kg	6.3	Lal, 2004
(b) Insecticide	kg	5.1	Lal, 2004
(c) Fungicide	kg	3.9	Lal, 2004
Electricity	kWh	0.608	Khodi and Mousavi, 2009

The data analysis was carried out with the help of the Microsoft Excel and Frontier Analyst software.

3 Results and Discussion

The results of CCR and BCC DEA models are illustrated in Figure 1. The technical efficiency estimation indicated that 13 and 29 farmers were efficient under the CCR and BCC model respectively. In other words, from the total of 67 farmers considered for the analysis, 29 farmers (43.28%) had the pure technical efficiency score of unity. Also, from the pure technically efficient farmers 13 farmers (19.40%) had the technical efficiency score of unity. From efficient farmers 13 were the fully efficient farmers in both the technical and pure technical efficiency scores; indicating that they were globally efficient and operated at the most productive scale size of production; however, the remainder of 16 pure technically efficient farmers were only locally efficient ones; it was due to their disadvantageous conditions of scale size. From inefficient farmers 14 and 21 had their technical and pure technical efficiency scores in the 0.9–0.99 range. It meaned that the farmers should be able to produce the same level of output using their efficiency score of its current level of energy input when compared to its benchmark which was constructed from the best performers with similar characteristics. From efficient farmers 13 ones had a scale efficiency of unity.

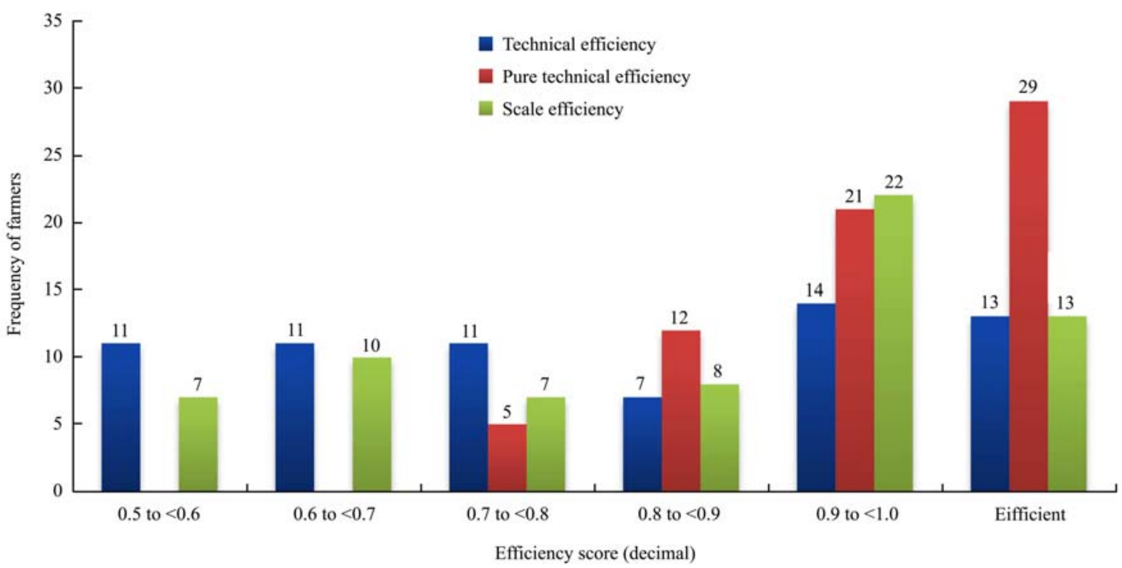

Figure 1 Efficiency score distribution of barley producers

Omid et al. (2011) studied the degree of technical efficiency (TE) and scale efficiency (SE) of cucumber greenhouses in Iran. The results showed that from the total of 18 greenhouses 12 farmers had the pure technical efficiency score of unity. Also from the pure technically efficient greenhouses 8 greenhouses had the technical efficiency score of unity. Also the TE of the inefficient greenhouses, on average, was calculated as 91.5%. This implies that the same level of output could be produced with 91.5% of the resources if these units were performing on the frontier.

The summarized statistics for the three estimated measures of efficiency are presented in Table 4. The results revealed that the average values of technical, pure technical and scale efficiency scores were 0.788, 0.941 and 0.833, respectively. Moreover the technical efficiency varied from 0.503 to 1, with the standard deviation of 0.263, which was the highest variation between those of pure technical and scale efficiencies. The wide variation in the technical efficiency of farmers implied that all the farmers were not fully aware of the right production techniques or did not apply them at the proper time in the optimum quantity (Mohammadi et al., 2011).

Table 4 Average technical, pure and scale efficiency of barley farmers

Particular	Average	SD	Min	Max
Technical efficiency	0.788	0.263	0.503	1
Pure technical efficiency	0.941	0.154	0.72	1
Scale efficiency	0.833	0.16	0.501	1

Mohammadi et al. (2011) applied DEA technique to determine the efficiencies of farmers in kiwifruit production in Iran. They reported that, the technical, pure technical and scale efficiency scores were as 0.942, 0.993 and 0.948, respectively. In another study, the efficiency of soybean production was analyzed and these efficiency indices were reported 0.853, 0.919 and 0.926, respectively (Mousavi–Avval et al., 2011). The average and standard deviation of cross efficiency scores for 10 truly most efficient farmers are showed in Table 5. These cross efficiency scores was calculated using CCR model. The results revealed that farmers Nos. 34, 32 and 19 with the average cross efficiency scores of 0.904, 0.901 and 0.896 had the highest average cross efficiency scores, respectively; therefore, these farms can be used as terms of benchmarking and establishing the best practice management.

Table 5 Average cross efficiency (ACE) score for 10 truly most efficient farmers base on the CCR model

Farmer No.	ACE	SD	Farmer No.	ACE	SD
34	0.904	0.231	40	0.873	0.241
32	0.901	0.221	15	0.869	0.267
19	0.896	0.199	41	0.867	0.263
28	0.882	0.198	37	0.864	0.271
39	0.879	0.262	12	0.852	0.272

Table 6 summarizes the optimum energy requirement and energy saving (MJ ha^{-1}) from different sources in barley production based on the results of BCC model. The results revealed that the total optimum energy requirement for barley production was 22,162.16 MJ ha^{-1}. We note from Table 6 that the possible overall energy saving is 11.45%, indicating that by following the recommendations resulted from this study, on average, about 2,865.31 MJ ha^{-1} of total input energy could be saved while holding the constant output level of barley yield.

In DEA method an inefficient unit can be made efficient either by reducing the input level while the output was fixed (input oriented), or by increasing the output level while input was fixed (output oriented). In this study we used input oriented. Therefore the barley yield was as same as present quantity.

Table 6 Optimum energy requirement and saving energy for barley production

Input	Optimum energy requirement /MJ ha^{-1}	Energy saving		Contribution input to saving /%
		MJ ha^{-1}	%	
1. Human labor	147.49	15.72	9.63	0.55
2. Machinery	989.64	152.75	13.37	5.33
3. Diesel fuel	5121.99	741.57	12.65	25.88
4. Chemical fertilizers	5536.89	999.47	15.29	34.88
5. Farmyard manure	353.37	45.63	11.44	1.59
6. Biocides	141.53	42.13	22.95	1.47
7. Electricity	6939.73	598.55	7.94	20.89
8. Seed	2931.52	269.48	8.42	9.41
Total energy	22162.16	2865.31	11.45	100

Omid et al. (2011) reported that on an average, about 8.5% of the total input energy for cucumber production in Iran could be saved.

The shares of the various sources from total input energy saving are presented in the last column of Table 6. It was evident that 34.88% of chemical fertilizers, 25.88% of diesel fuel and 20.89% of electricity energy could be saved which had the highest inefficiencies. Also the shares of human labor, machinery, farmyard manure, biocides and seed energy inputs were relatively low, indicating that, they have been used in the right proportions by almost all the farmers.

The improvements of energy indices for barley production are presented in Table 7. Energy use efficiency was calculated as 2.86 and 3.23, in present and target use of energy, respectively, showing an improvement of 12.94%. Also, energy productivity, specific energy and net energy in target conditions were found to be 0.22 kg MJ^{-1}, 4.55 MJ kg^{-1} and 49,363.19 MJ ha^{-1}, respectively. The distribution of inputs used in the production of barley according to the direct, indirect, renewable and non–renewable energy groups, are also given in Table 7. It was evident that by optimization of energy input, the shares of direct and non–renewable energy with respect to total energy input increased and also the shares of indirect and renewable energy forms symmetrically decreased.

In Table 8 the pure technical efficiency (PTE), actual energy use and optimum energy requirement from different energy sources for individual inefficient farmers are showed. Also their average and standard deviation values are presented. Using this information, it was possible to advise a producer regarding the better operating practices by following his/her target energy requirement from different inputs to reduce the input energy levels to the target values while achieving the output level presently achieved by him. So dissemination of these results will help to improve efficiency of farmers for barley production in the surveyed region. In the last column of Table 8 the ESTR percentage for 38 inefficient farmers are presented. As it can be seen, for inefficient farmers, ESTR ranged from 0.4% (farmer No. 65) to 37.8% (farmer No. 2), with the average of 13.9% indicating that between inefficient farmers, Nos. 65 and 2 were the best and the worst inefficient ones, respectively.

Table 7 Improvement of energy indices for barley production

Items	Unit	Present quantity	Optimum quantity	Difference /%
Energy use efficiency	–	2.86	3.23	12.94
Energy productivity	kg MJ^{-1}	0.19	0.22	15.55
Specific energy	MJ kg^{-1}	5.14	4.55	–11.48
Net energy	MJ ha^{-1}	46497.90	49363.19	6.16
Direct energy	MJ ha^{-1}	13565.05 (54.20%)[a]	12209.21 (55.09%)	–9.99
Indirect energy	MJ ha^{-1}	11462.42 (45.80%)	9952.95 (44.91%)	–13.17
Renewable energy	MJ ha^{-1}	8531.29 (34.09%)	7532.76 (33.99%)	–11.70
Non–renewable energy	MJ ha^{-1}	16496.18 (65.91%)	14629.40 (66.01%)	–11.32
Total energy input	MJ ha^{-1}	25027.47	22162.18 (100%)	–11.45

Note: [a] Numbers in parentheses indicate percentage of total optimum energy requirement.

Table 8 The source wise actual and target energy use for inefficient farmers in the barley production (based on BCC Model)

DMU	PTE	actual energy use/MJ ha^{-1}							Optimum energy requirement /MJ ha^{-1}							ESTR /%
		Labor	Machinery	Diesel	Fertilizer	Biocide	Electricity	Seed	Labor	Machinery	Diesel	Fertilizer	Biocide	Electricity	Seed	
1	0.82	159.7	1536.2	6700.9	8301.6	360	7251.8	4410	131.2	1087.5	5505.5	5070.3	137.1	5958	2900.7	27.6
2	0.75	228.3	2100.5	8615.4	10933.7	360	8138.6	3675	170.2	1071.2	5298.7	5677.9	173.4	6065.7	2739	37.8
3	0.78	191.1	1473.5	7151.4	5030.5	156	7334.8	3675	148.2	966.9	5039.5	3900.6	100	5687.4	2849.6	25.3
4	0.84	181.8	1379.4	6869.8	6801.6	156	7152.1	3675	151.9	1009.3	5384	4472.8	130.4	5977	3071.2	23
5	0.83	182.3	1316.7	5518.4	5030.5	156	7700.1	3234	150.7	922.9	4561.5	4158.2	128.9	6316.2	2371.8	19.6
6	0.72	184.2	1943.7	7827.1	8301.6	480	8133	3675	132.9	1008.4	5060.9	4432.6	113	5868.8	2651.9	36.9
7	0.9	154.8	1285.4	5968.9	6801.6	156	8245.4	3675	139.7	1089.7	5264.8	6134.4	140.7	7436.5	3314.5	10.5
8	0.96	135.2	1348.1	6813.5	8267.7	360	7264.7	2940	129.5	963	5533	6073.4	169.2	6955.9	2815.1	16.6
9	0.97	136.2	1222.7	7095.1	8301.6	360	6041.3	3675	132.3	1091.8	5599.3	4857.4	108.3	5868.5	2940	23.2
11	0.97	163.7	1285.4	5631	4425.3	60	6598.5	2940	158.7	930.1	5122.1	4290.8	58.2	6397.9	2850.6	6.1
13	0.84	206.8	1160	5631	8289.8	120	6969.4	3234	172.7	931	4703.6	4455	100.2	5821.6	2391.6	27.5
16	0.95	171.5	1097.3	5293.1	3259.3	180	6598.5	3675	162.3	927.9	5008.9	3084.3	110.8	6244.2	3044.3	8.3
18	0.9	151.9	971.9	5124.2	6518.6	180	8796.2	3234	137.3	878.6	4632.8	5893.5	162.7	7542.4	2721.7	12
21	0.81	242.1	971.9	6363	5030.5	120	6164.5	3675	196.9	790.6	4588.4	3574.6	39.1	5014.8	2675.5	25.2
22	0.83	204.8	1254	7376.6	4108.3	240	7261.7	2940	145.6	881.7	4431.8	3421.8	115.5	6048.3	2448.7	25.2

DMU	PTE	actual energy use/MJ ha^{-1}							Optimum energy requirement /MJ ha^{-1}							ESTR /%
		Labor	Machinery	Diesel	Fertilizer	Biocide	Electricity	Seed	Labor	Machinery	Diesel	Fertilizer	Biocide	Electricity	Seed	
23	0.98	247.9	1065.9	5490.2	5347.5	240	6164.5	2205	146.9	965	4393.3	4062.8	118	6069.6	2171	13.7
25	0.95	248.9	1065.9	5518.4	4459.3	240	6603	2205	145.6	899.2	4117.5	4155.5	189.6	6302.5	2104.7	11.9
26	0.72	213.6	1285.4	9516.4	6813.5	240	12315.8	2940	150.2	925.8	4478.8	4907.7	172.9	6812.8	2117.7	41.3
27	0.79	186.2	1379.4	8165	4391.4	240	9161.6	3087	136	976.3	4573.7	3466.5	141.5	6755.7	2436.9	30.5
30	0.91	156.8	1379.4	7376.6	17145.6	150	11283.9	4116	143.3	1155.5	5214.2	8740.1	137	8504.7	3758.7	33.5
36	0.87	187.2	1160	7725.7	17428.6	360	10776.3	4851	162.5	1007.2	6254.5	15057.9	312.6	9352.4	4212.1	14.4
38	0.95	168.6	1128.6	7432.9	12681.1	360	9347	4116	160.3	1073.2	6282.2	12058.5	342.3	8888.1	3906.7	7.2
43	0.85	167.6	1348.1	5856.2	8493.6	0	8357.8	2940	142.2	985.2	4969	4638.9	0	6787	2494.6	26.3
44	0.97	163.7	1078.4	4645.6	4176.3	120	7146.6	2205	137.3	919	4504.8	4049.8	89.3	6193.2	2138.2	7.7
45	0.83	166.6	1128.6	5180.5	5709.2	240	7147.5	2646	135.7	880.6	4209.5	3818.9	129	5921	2191.9	22.2
46	0.91	159.7	1003.2	5912.6	4555.5	0	6963.9	2940	144.8	887.2	4979.9	4130.5	0	6268.4	2181.5	13.7
48	0.97	154.8	909.2	6137.8	5313.5	204	7149.3	2205	148.3	885.1	4286.1	4902.6	198.6	6959.9	2146.6	11.5
49	0.97	149.9	1034.6	5208.7	5709.2	276	5864.1	2940	145.3	982	5048.8	4313.4	99.9	5684.1	2695.3	10.5
50	0.98	146	1254	5433.9	4292.3	300	6598.5	2205	143.4	939.5	4518.7	4216.3	101.2	6161	2166	9.8
56	0.99	147	1128.6	5462.1	5030.5	0	6415.9	2940	146	956.1	4934.6	4482.5	0	6374.2	2440	8.5
58	0.99	140.1	1222.7	5631	6518.6	120	5864.1	3087	139	1081.3	5587.1	4945.1	119.1	5818.4	2980.9	8.5
59	0.89	153.9	1160	5602.8	6801.6	156	7480.9	3675	136.3	1027.8	4964.7	4863.7	138.2	6628.8	3021.1	17
61	0.94	135.2	1128.6	4758.2	6801.6	240	6777.5	2940	126.9	962.8	4464.1	4611.3	107	6358.7	2758.3	14.9
63	0.89	145	1222.7	4955.3	8117.7	120	6960.2	2940	128.9	942.6	4403.8	4478.1	106.6	6185.5	2612.8	22.9
64	0.99	120.5	1160	4899	6801.6	120	6408.5	3675	119.1	1102.3	4839.2	5468.1	102.3	6330.3	3294.5	8.3
65	0.99	120.5	1128.6	5687.3	5030.5	120	6043.1	2940	113	1103	5670	5020	120	6040	2912	0.4
66	0.86	194	1316.7	5574.7	4425.3	60	8065.5	2940	165.2	881	4745.7	3767.3	51.1	5880.5	2502.8	20.3
67	0.99	121.5	1034.6	5293.1	3259.3	120	6157.9	3234	120.3	1024.2	5240.2	3226.7	118.8	6096.3	3201.7	1
Ave.	**0.9**	**170.8**	**1238.7**	**6195.9**	**6808**	**196.6**	**7492.2**	**3218.5**	**144.7**	**976.6**	**4958.3**	**5075.8**	**123.2**	**6462.5**	**2743**	**13.9**
S.D.	**0.1**	**34**	**236.4**	**1164**	**3217.4**	**114.1**	**1481.5**	**619.7**	**16.2**	**82.6**	**523.4**	**2288.7**	**68**	**877.9**	**502**	**10.2**

For calculating the greenhouse gas emissions, the CO_2 emission coefficient of agricultural inputs was used. These coefficients were used in several papers (Table 3). The greenhouse gas emissions from different inputs in barley production in present and target condition are shown in Table 9. The result showed that total amount of CO_2 was 885.56 kg ha^{-1} in present condition. The highest value of GHG emission belonged to electricity with 384.18 kg CO_{2eq} ha^{-1} and share of 43.38% of total emission, followed by diesel fuel (287.40 kg CO_{2eq} ha^{-1} and 32.45%). As can be seen from Table 9, by optimization of energy inputs in barley production, the total CO_2 emissions can be reduced to 787.60 kg CO_{2eq} ha^{-1}.

The main objective of this study was to show the extra use of energy in every input and explain about the advantages of reducing energy on agriculture and environment. The government can apply some strategies to reach the plan of this study. Increasing in output related to a lot of options and some parameters can effect on yield such as environmental condition and farmers can't control it, so optimization in inputs can be useful.

In a research conducted in Canada, the greenhouse gas emissions from wheat production were reported as 410 kg CO_{2eq} ha^{-1} to 1,130 kg CO_{2eq} ha^{-1}, depending on fertilizer rate, location and seeding system (Khakbazan et al., 2009). Pishgar–Komleh et al. (2012) calculated the 992.88 kg CO_{2eq} ha^{-1} for potato production in Esfahan province of Iran. They reported that the highest value of GHG emission belonged to chemical fertilizer with share of 37% of total emission.

Table 9 Greenhouse gas emissions of inputs in barley production in present and target condition

Difference /%	Optimum quantity /kg CO_{2eq} ha^{-1}	Present quantity /kg CO_{2eq} ha^{-1}	Inputs
–13.38	70.26	81.11	1. Machinery
–12.65	251.05	287.40	2. Diesel fuel
–14.77	106.60	125.07	3. Chemical fertilizers
–22.95	6.01	7.80	4. Biocides
–7.94	353.68	384.18	5. Electricity
–11.06	787.60	885.56	Total

4 Conclusions

In this study, the nonparametric method of DEA was used to analyze the efficiencies of barley producers in Hamedan province of Iran in energy points of view. This method can show the extra consume of energy for farmers and show the advantages of optimization in input on environment and cost of each input. Based on the results of the investigations, the following conclusions were drawn:

1) There has been no study on modeling barely production with respect to input energies using nonparametric method of DEA in Hamedan province of Iran. The results of this work were useful and practical for government and farmers in the area to manage the inputs and increase the benefits of agriculture. From the total of 67 farmers, considered for the analysis, 19.4% and 43.3% were found to be technically and pure technically efficient, respectively.

2) The average values of technical, pure technical and scale efficiency scores of farmers were found to be 0.788, 0.941 and 0.833, respectively.

3) The energy saving target ratio for barley production was calculated as 11.45%, indicating that by following the recommendations resulted from this study, about 2865 MJ ha^{-1} of total input energy could be saved while holding the constant level of barley yield. This amount of energy was equivalent of 51 liter of diesel fuel, it was not too much by it was important because it can show the level of efficient in barely farms in this area and some new practical strategies can reduce this amount.

4) The chemical fertilizer energy had the highest potential for improvement by 34.88%, followed by diesel fuel energy inputs.

5) Reducing diesel fuel consumption and fertilizer usage, mainly nitrogen, is important for energy management. A saving in diesel fuel by improving tillage system may be possible.

6) The result showed that total amount of CO_2 emission was 885.56 and 787.60 kg CO_{2eq} ha^{-1} in present and target condition, respectively. This part was very important in this research and it was new and very useful. If the farmers can reduce the input energy, actually they will decrease CO_2 emission and can keep the environment clearly for future.

References

Adler, N., L. Friedman,and Z. Sinuany –Stern. 2002. Review of ranking methods in the data envelopment analysis context. *European Journal of Operational Research,* 140(2): 249–265.

Angulo-Meza, L., and M. P. E. Lins. 2002. Review of methods for increasing discrimination in data envelopment analysis. *Annals of Operations Research*, 116(1–4): 225–242.

Anonymous. 2013. Iran annual agricultural statistics. Ministry of Jihad–e–Agriculture of Iran. www.maj.ir. Accessed in July 2013.

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

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

Banker, R., A. Charnes, and W. Cooper. 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, 30(9): 1078– 1092.

Charnes, A., W. W. Cooper, and E. Rhodes. 1978. Measuring the efficiency of decision-making units. *European Journal of Operational Research,* 2(4): 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(7–8): 1063–1085.

Dyer, J. A., and R. L. Desjardins. 2006. Carbon dioxide emissions associated with the manufacturing of tractors and farm machinery in Canada. *Biosystems Engineering,* 93(1): 107–118.

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

Khakbazan, M., R. M. Mohr., D. A. Derksen, M. A. Monreal, C. A. Grant, R. P. Zentner, A.P. Moulin, D. L. McLaren, R. B. Irvine, and C. N. Nagy. 2009. Effects of alternative management practices on the economics, energy and GHG emissions of a wheat-pea cropping system in the Canadian prapFrairies. *Soil & Tillage Research,* 104(1): 30–38.

Khodi, M. and S. Mousavi. 2009. Life cycle assessment of power generation technology using GHG emissions reduction approach. 7th National Energy Congress, 22-23. Desember, Tehran, Iran (in Persian).

Lal, R. 2004. Carbon emission from farm operations. *Environment International,* 30(7): 981–990.

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.

Mobtaker, H. G., A. Keyhani, A. Mohammadi, S. Rafiee, and A. Akram. 2010. Sensitivity analysis of energy inputs for barley production in Hamedan province of Iran. *Agriculture, Ecosystems and Environment,* 137(3–4): 367–372.

Mohammadi, A., S. Rafiee, S. S. Mohtasebi, S. H. Mousavi–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.

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

Mousavi-Avval, S. H., A. Mohammadi, S. Rafiee, and A. Tabatabaeefar. 2012. Assessing the technical efficiency of energy use in different barberry production systems. *Journal of Cleaner Production*, 27, 126–132.

Nassiri, S. M. and S. Singh. 2009. Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. *Applied Energy*, 86(7–8): 1320–1325.

Omid, M., F. Ghojabeige, M. Delshad, and H. Ahmadi. 2011. Energy use pattern and benchmarking of selected greenhouses in Iran using data envelopment analysis. *Energy Conversion and Management*, 52(1): 153–162.

Onut, S. and S. Soner. 2007. Analysis of energy use and efficiency in Turkish manufacturing sector SMEs. *Energy Conversion and Management*, 48(2): 384–394.

Pahlavan, R., M. Omid, S. Rafiee, and S. H. Mousavi–Avval 2012. Optimization of energy consumption for rose production in Iran. *Energy for Sustainable Development,* 16(2): 236–241.

Pishgar–Komleh, S. H., M. Ghahderijani, and P. Sefeedpari. 2012. Energy consumption and CO_2 emissions analysis of potato production based on different farm size levels in Iran. *Journal of Cleaner Production*, 33, 183–191.

Sexton, T. R., R. H. Silkman, and A. J. Hogan. 1986. Data envelopment analysis: Critique and extensions. In: Silkman, R.H. (Ed.), Measuring Efficiency: An Assessment of Data Envelopment Analysis, Jossey–Bass, San Francisco. CA. 73–105.

Singh, H., D. Mishra, and N. M. Nahar. 2002. Energy use pattern in production agriculture of typical village in arid zone, India: part I. *Energy Conversion Management*, 43(16): 2275–2286.

Tabatabaie, S. M. H., S. Rafiee., A. Keyhani, and A. Ebrahimi. 2013. Energy and economic assessment of prune production in Tehran province of Iran. *Journal of Cleaner Production*, 39, 280–284.

Taki, M., R. Abdi, M. Akbarpour., and H. G. Mobtaker. 2013. Energy inputs – yield relationship and sensitivity analysis for tomato greenhouse production in Iran. *CIGR Journal*, 15(1): 59–67.

Taki, M., A. Mahmoudi, H. G. Mobtaker, and H. Rahbari. 2012. Energy consumption and modeling of output energy with multilayer feed-forward neural network for corn silage in Iran. *CIGR Journal*, 14(4): 93–101.

Zhang, X., G. H. Huang, Q. Lin, and H. Yu. 2009. Petroleum–contaminated groundwater remediation systems design: A data envelopment analysis based approach. *Expert Systems with Applications*, 36(3): 5666–5672.