African Journal of Agricultural Research Vol. 6(27), pp. 5978-5986, 19 November, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1117
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Optimization of energy consumption for wheat production in iran using data envelopment analysis (DEA) technique

Houshang Bahrami[1], Morteza Taki[2]* and Nasim monjezi[1]

[1]Department of Agricultural Machinery, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran.
[2]Department of Agricultural Machinery, Tabriz University, Iran.

Accepted 11 October, 2011

In this study a non-parametric method of Data Envelopment Analysis (DEA) was used to estimate the energy efficiencies of wheat producers based on six energy inputs including human power, diesel fuel, machinery manufacture and depreciation, water for irrigation, transportation, seed, fertilizer, and chemicals also with single output of grain yield. This study helps to rank efficient and inefficient farmers and to identify optimal energy requirement and wasteful uses of energy. Data were collected using face-to-face surveys from 90 farms in Khozestan Province which is the most important center of wheat production in Iran. Based on the results, average energy consumption for wheat production was 58367.69 MJha^{-1}. Also, the results of DEA application showed that, the technical, pure technical and scale efficiencies of farmers were 87.97, 91.18, and 96%, respectively. Moreover, energy saving target ratio for wheat production was calculated as 15%, indicating that by following the recommendations resulted from this study, about 8755.1 MJ ha^{-1} of total input energy could be saved while holding the constant level of wheat yield.

Key words: Data enveloping analysis, efficient units, energy efficiency, technical efficiency.

INTRODUCTION

The high rate of population growth and reducing the extent of fertile land due to the increasing development of urban and industrial areas induce more efficient use of existing facilities. The effective and efficient use of limited resources like water, soil and human power are of particular importance to provide food requirements for people in developing countries, including Iran. Successful efforts to achieve self sufficiency and growth of gross national income like any other activity requiring deep knowledge of the practical and economic processes and applying the latest knowledge and technology around the world (Gheisari et al., 2007). Agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energies, such as seed, manure and animate energy, and commercial energies directly and indirectly in the form of diesel, electricity, fertilizer, plant protection, chemicals, irrigation water and machinery (Kizilaslan, 2009). Efficient use of energies helps to achieve increased production and productivity and contributes to the economy, profitability and competitiveness of agriculture sustain-ability in rural living (Singh et al., 2002). Wheat is one of the top three most producing cereals in the world, it ranks in second place after corn and followed by rice. Winter wheat is one of the most major crops that have been planted in Iran. Planted area was 12.96 million ha in 2008 to 2009. Cereal planted area was 9.37 (72.28%) million ha, which includes wheat (73.24%), barely (16.73%), paddy (6.73%) and corn (3.12%). Total harvested cereals in 2005 to 2006 were 22.40 million tons of which wheat recorded 65.47% followed by barely (13.20%), paddy (11.66%) and corn (9.67%) respectively (Anonymous, 2009). At least 40% of Iran's wheat is dry with an average yield of only 0.8 tons ha^{-1}. Even in irrigated farms, the average yield of wheat rarely exceeds 3 tons ha^{-1}, which is low in comparison to the world standards (Anonymous, 2008).

In recent years, data envelopment analysis (DEA) has become a central technique in productivity and efficiency

*Corresponding author. E-mail: Mtaki88@ms.tabrizu.ac.ir. Tel: +9809139204415. Fax: +9804113356007.

Table 1. Energy equivalent of energy output and input in agricultural production.

Energy Inputs	Unit	Energy equivalent (MJ kg^{-1})	References
Human power	Hour	1.96	Chaudhary et al., 2006
Tractor	kg	93.61	Kaltschmittn et al., 1997
Combine	kg	87.63	Kaltschmittn et al., 1997
Nitrogen (N)	kg	47.1	Karkacıer and Goktolga, 2005
Phosphate	kg	15.8	Karkacıer and Goktolga, 2005
Potassium	kg	9.28	Karkacıer and Goktolga, 2005
Seed	kg	25	Mandal et al., 2002
Straw	kg	12.5	Mandal et al., 2002
Machinery	kg	62.7	Chaudhary et al., 2006
Pesticide	Lit	101.2	Yaldiz et al., 1993
Herbicide	Lit	238	Karkacıer and Goktolga, 2005

analysis applied in different aspects of economics and management sciences. Although within this context, several researchers have focused on determining efficiency in agricultural units and various products ranging from cultivation and horticulture to aquaculture and animal husbandry for example: surveying the quantity of inefficient resources which are used in cotton production in Panjab in Pakistan (Shafiq and Rehman, 2000), reviewing energy performance used in paddy production (Nassiri and Singh, 2009), surveying improving energy efficiency for garlic production (Samavatian et al., 2009), evaluation and development of optimum consumption of energy resources in greenhouse cultivation in Tehran Province (Gochebeyg et al., 2009), checking the efficiency and returning to the scale of rice farmers in four different areas of Panjab State in India by using non-parametric method of data envelopment analysis (Nassiri and Singh, 2010), determination of the amount of energy consumption in wheat cultivation of Fars Province with the approach of data envelopment analysis (Houshyar et al., 2010). A further comparative review of frontier studies on agricultural products can be found in Sharma et al. (1999), Iraizoz et al. (2003), Galanopoulos et al. (2006), Singh et al. (2004), Chauhan et al. (2006), Banaeian et al. (2010), Mousavi-Avval et al. (2010) and Banaeian et al. (2011).

Based on literature, there was no study on optimization of energy inputs for wheat production in Khozestan Province of Iran. So, the objectives of this research were to specify energy use pattern for wheat production, analyze the efficiencies of farmers, rank efficient and inefficient ones and to identify target energy requirement and wasteful uses of energy from different inputs for wheat production in Khozestan Province of Iran.

MATERIALS AND METHODS

Selection of case study farms and data collection

Ahvaz County is in a Longitude of 48° and 40' E and Latitude of 31°and 20' N from equator. It is located in the height of 18 m above the sea level. Its area is 20477 ha, which includes rural districts of Bavi, Elhai, Hamidie, Gabir, Susie, Sofhe, Gambue, and Ghizanie. Fertile lands of this city, which have been used for cultivating wheat in irrigated lands, were 104000 ha in the cultivation period of 2010 to 2011(Anonymous, 2010). To obtain farmers sample volume, Cochran formula was used (Cochran, 1977):

$$n = \frac{N(t.s)^2}{Nd^2 + (t.s)^2} \quad (1)$$

n = sample volume, N = population size, T = acceptable reliability which is obtained from T-student table (desired adjective is assumed normal), S^2 = estimation variance of the trait studied, d = desired probable accuracy.

An experimental survey is done in a small scale to obtain probable errors and to estimate approximate trait studied; as the aforementioned parameters initially have no determined trait variance. Initial sampling data was analyzed, and then data related to trait studied from the population was obtained approximately. Eventually, the earlier determined parameters were put in the Cochran formula to obtain the main sample volume. Thus, sample volume for 90 farmers of Ahvaz County was obtained.

Energy equivalents used

To estimate the amount of energy used to produce field crops, it is necessary to determine energy equivalents for machinery manufacturing, depreciation, fuel consumption for operations, irrigation, labor, fertilizer, agricultural pesticides and seed, and their shares should be specified in total energy inputs. As a matter of fact, the condition of field operations in different stages from tillage up to harvesting should be specified. The amounts of input were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. The previous studies were used to determine the energy equivalents coefficients. These sources are given in Table 1. Some indices are defined and used to determine relations between input and output energies. By using those indices, energy of different products in different farming systems can be compared. These indices are shown in Equations 2, 3 and 4 (Mohammadi et al., 2008):

Energy ratio (ER): a dimensionless number which is equivalent with the ratio of input to output. [2]

Energy productivity (EP): is equivalent with weight function of product to input energy ($kgMJ^{-1}$). (3)

Net energy gain (NEG): is equivalent with output energy minus input energy ($MJha^{-1}$). (4)

The amount of energy consumption for each input is multiplied to its equivalent energy of that level, to obtain energy indices.

Data envelopment analysis technique

There are too many methods for evaluating efficiency and measuring technical efficiency of productive units. These methods are divided into two groups of parametric and non-parametric methods. In the parametric method, a determined production function is estimated by using different statistical methods and econometrics. Therefore, the efficiency was determined by using that function. The second group is a non-parametric method; its main property is that it does not need any specific distribution or figure of mathematical function. Data envelopment analysis is one of the most important non-parametric methods (Charnes et al., 1984). DEA is a linear programming model that attempts to maximize a service unit's efficiency within the performance of a group of similar service units that are delivering the same service.

In their original paper, Charnes et al. (1984) introduced the generic term ''decision making units'' (DMU) to describe the collection of firms, departments, or divisions which have multiple incommensurate inputs and outputs and which are being assessed for efficiency. Since then, it has been successfully deployed in many different sectors to assess and compare the efficiency of DMUs (Banker et al,. 1984). The DEA models deployed in this study are Charnes, Cooper and Rhodes (CCR); Banker, Charnes, and Cooper (BCC). In this study, 90 questionnaires were prepared to evaluate farms, and determine input energy consumption for wheat production in irrigated land. Questionnaires were filled by face to face interview; after that obtained data were used as an input in Excel software. Eventually, they were analyzed by using data envelopment analysis. Efficient and inefficient units, and also used input and produced output were determined, by evaluating energy consumptions and efficiency of all of the production units. Finally, energy consumption of each unit was obtained, additionally total energy consumption in the studied farms was obtained by using the energy of each unit (Table 1).

CCR and BCC methods

Analyzing the data was done by using CCR[1] and BCC[2] methods. Choosing a proper DEA model depends on controlling input and output; therefore, a model would be chosen according to the most controllable input. As changing input is practicable in this study, so CCR and BCC models, which are input based models, were used (Equations 5 and 6). Efficient and inefficient models were determined, in addition, different pure technical efficiencies and scale efficiency were calculated, by using CCR and BCC models:

$$\begin{aligned} &\max E_p = \sum_{r=1}^{r=s} U_r Y_{rp} \\ &\sum_{i=1}^{i=m} V_i X_{ip} = 1 \\ &\sum_{r=1}^{r=s} U_r Y_{rj} - \sum_{i=1}^{i=m} V_i X_{ij} \leq o,\ j = 1,2,...,n \\ &V_i \geq \varepsilon, U_r \geq \varepsilon \end{aligned} \tag{5}$$

1- Charns, Cooper and Rhodes

2- Banker, Charns and Cooper

$$\begin{aligned} &\max E_p = \sum_{r=1}^{r=s} U_r Y_{rp} + w \\ &\sum_{i=1}^{i=m} V_i X_{ip} = 1 \\ &\sum_{r=1}^{r=s} U_r Y_{rj} - \sum_{i=1}^{i=m} V_i X_{ij} + w \leq o,\ j = 1,2,...,n \\ &U_r \geq \varepsilon, V_i \geq \varepsilon, w\ free \end{aligned} \tag{6}$$

In the aforementioned formulas, j = 1, 2, …, n and "n" is the number of DMU s, "s" is the number of outputs, and "m" is the number of output, X_{iP} is the quantity of "*i*" input for DMU_p, and Y_{rP} is the quantity of "*r*" output for DMU_p, U_k, V_j that are respectively weight of output and output; E_p is "*i*" unit efficiency ratio (Banker et al., 1984). If we want to have reliable results from data envelopment analysis, it is essential to calculate the minimum decision units from Equation 7 (Yong and Chunweki, 2003):

Decision units ≥ (I + O) 3 (7)

In Equation 7, "I" is the number of input and "O" is the number of output. In this study, production inputs included machinery energy, fuel consumption, energies of seed, fertilizer, and pesticide, and human power, energy of consumed water and transportation energy. And production energy (performance) was considered as output. Therefore, the minimum number of decision units which are used for analyzing is equal with:

The number of decision = 3(6+1) =21 (8)

25 units were selected randomly among 90 selecting samples. It is possible to obtain reliable results; because the number of selecting units is bigger than the minimum of decision making units (Mohammadi, 2008). The relation among technical efficiency, pure technical efficiency (managing performance) and scale efficiency is defined as follows (Emami, 2000):

Scale efficiency = technical efficiency/ pure technical efficiency (9)

The quantity of scale efficiency will not be more that one. The efficiency of CCR model is called technical efficiency, as it is not under the effect of scale and size. On the other hand, BCC shows pure technical efficiency under the effect of efficiency to variable scale. The aforementioned formula shows analyzing the efficiency, and also demonstrates resources of efficiency. In fact, it determines the cause of inefficiency; whether it is related to managing inefficiency or the condition of scale efficiency or even both of them (Gheisari et al., 2007).

RESULTS

Energy use pattern

Table 2 shows the energy equivalents and ranking of the inputs for wheat production in the studied area. The results revealed that 1579.12 MJ of human power and 3278.24 MJ of Machinery manufacture and depreciation were required per hectare of wheat production. The majority of human power in the farms was used in the harvest and transportation operations. Additionally, 7981.34 MJ of diesel fuel (14% of the total energy in operations) was consumed for the machinery purposes.

Diesel fuel was spent for operations, such as land

Table 2. Energy used status for wheat production in Ahvaz County.

Input	Equivalent energy (MJ/ha)	Percent of total
Machinery manufacture and depreciation	3278.24	5
Fuel consumption	7981.34	14
Irrigation	4673.45	8
Human power	1579.12	3
Seed, fertilizer, and chemicals	**39875.2**	**68**
Transportation	980.34	2
Total	58367.69	100

Table 3. Energy indices for wheat production in Ahvaz County.

Parameter	Unit	Amount
Energy productivity	$kgMJ^{-1}$	0.052
Energy intensity	$MJkg^{-1}$	19.53
Net energy gain (grain and straw)	GJ	63.2
Energy ratio (grain)	-	0.912
Energy ratio (grain and straw)	-	1.51

preparation, planting, harvesting and transportation. The energy equivalent of seed, fertilizer, and chemicals used for wheat growing was 39875 $MJha^{-1}$ and has the highest share of energy consumption. The other inputs applied in the growing process in the surveyed area are shown in Table 2. The last column gives the percentage of each input of the total energy input. Total mean energy used in various farm steps during wheat production was 58367.69 MJ ha^{-1} also the energy productivity, energy intensity, net energy and energy ratio of wheat production are presented in Table 3.

Efficiency estimation

According to the results obtained from Table 4, the mean of technical efficiency of inefficient farms for wheat production was calculated as 85% by using input based CCR model. Indeed, by using 85% of input and having the fixed quantity of output, inefficient units will become efficient, and save 15% of input by increasing its efficiency. According to the data of this Table, the farms No. 3, 9, 17, 18 and 22 are efficient. Efficiency of productive units means that every unit has to be able to decrease its consumption of every input to (1 - ϴ)%, without decreasing in production (Gochebeyg et al., 2009). The 79.6% efficiency of farm 7 means that for being an efficient unit, it has to decrease 24.4% of all the productive factors (without decreasing production). On the other hand, needed production factors for a specific level of input can be calculated; by considering the farm No.18 as the pattern of the Farms No.7, and variable decision coefficient of farm 7 in Table 4 which is 72.9%. So, to have farm No.7 efficient, it has to use 72.9% of the inputs of unit No.18, without decreasing in production.

Efficiency of wheat farms are illustrated in Figures 1 and 2, by using CCR and BCC models. From the total farmers considered, about 25% were globally efficient farmers and were operating at the most productive scale size; about 32% were only locally efficient, but not globally efficient because of their disadvantageous conditions of scale size; also the remaining 43% were inefficient farmers. In a productive unit, if it is completely efficient in BCC model, but is not efficient in CCR model; then it is in part efficient but does not have efficiency (in this condition total inefficiency is due to the inefficiency of the scale). But if the efficiency of both of these models is less than 100%, in this state, inefficiency is due to inefficiency of scale or the condition of productive unit or even managing inefficiency. Consequently, it is reasonable to determine the inefficiency of scale of a productive unit by using these two models (Gochebeyg et al., 2009).

According to the results obtained from Table 4, farms No.6, 13, and 21 are efficient to some extend; in other words, their pure technical efficiency is equal with one, but their overall efficiency is less than one. This inefficiency is due to scale inefficiency or managing inefficiency. Inefficiency of the other farms is due to managing inefficiency and the condition of the farms (scale inefficiency). When a productive unit is efficient in BCC model, the condition of efficiency to scale can be determined by using output weight. If it is less than zero, then the ratio of efficiency to scale is additive and if it is more than zero; the ratio of efficiency to scale is subtractive. If it is equal with zero then the ratio is constant. The scale of productive unit cannot be decreased while the ratio of efficiency to scale is additive but it can be maximized to infinity. The ratio of output to input for each point on the efficiency partition line is non-subtractive. It means that increasing of output is proportional with output to some extent. According to the results obtained from Table 5 Farms No.3, 9, 17, 18, and 22 have constant efficiency but the remains have additive efficiency.

Energy savings from different energy inputs

Table 6 illustrates the obtained results from analyzing

Table 4. Evaluation of wheat farms with reference units via CCR input oriented model.

DMU's	Efficiency (%)	Reference units with coefficients of decision
1	89.51	3 (87.57), 9 (86.12)
2	87.63	17 (67.45), 3 (48.18)
3	100	-
4	91.12	17 (86.15), 18 (27.28)
5	79.7	3 (35.76), 18 (67.14)
6	92.23	9 (79.47), 18 (48.19)
7	79.6	18 (72.9)
8	76.82	9 (87.57), 3 (86.12)
9	100	-
10	90.2	9 (79.47), 17 (48.19)
11	83.57	22 (24.9)
12	91.12	22 (46.18), 3 (78.14)
13	89.31	3 (43.19)
14	83.43	17 (35.16), 27 (27.18)
15	79.6	3 (48.19), 18 (40.24)
16	92.82	27 (65.3), 3 (60.29)
17	100	-
18	100	-
19	85.56	17 (78.34)
20	79.49	9 (71.46), 17 (37.12)
21	83.39	22 (34.56), 17 (67.9)
22	100	-
23	82.81	17 (45.23), 22(49.18)
24	76.23	3 (25.12), 17 (28.9)
25	85.12	9 (35.68), 22 (56.18)
Average of efficiency in inefficiency units	85	-

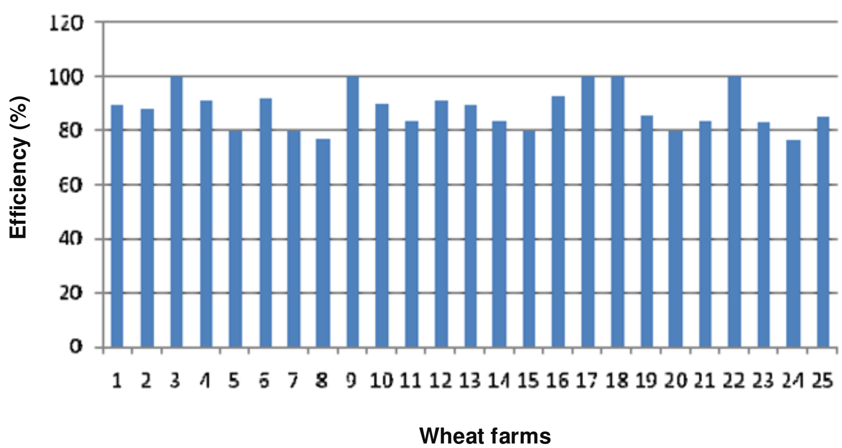

Figure 1. Efficiency of wheat production farms with CCR model.

wheat farms by using input basis Return to Constant Returns to Scale model. Data of this table are used for determining extra input and deficiency of efficiency. The specific quantity that each inefficient unit needs to decrease in order to become efficient is determined. As an illustration, the farm No.2 with the efficiency of 87.63% has to decrease 22891 units of fertilizer, seed, and pesticide input and 223 units of transportation input, and 1200 units of human power input, 1312 units of equipment and machinery input, and 6100 units of fuel

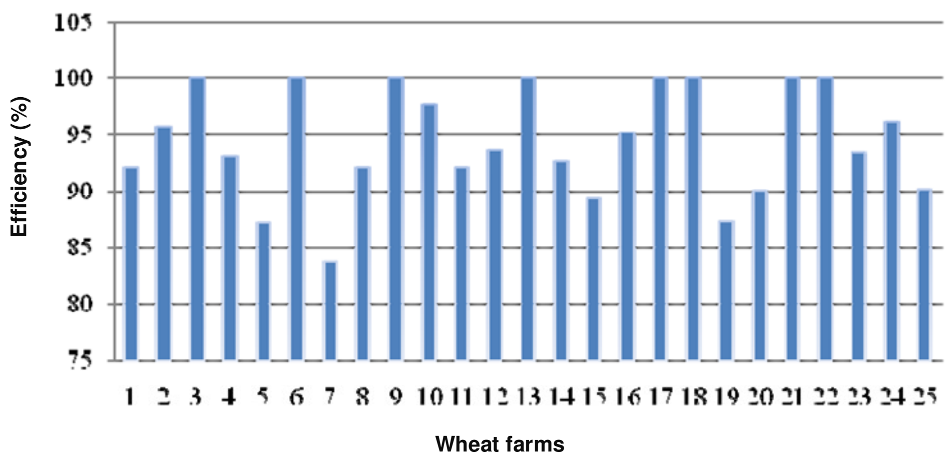

Figure 2. Efficiency of wheat production farms with BCC model.

Table 5. Analyses of efficiency and return to scale in wheat farms.

DMU's	E_{CCR}	E_{BCC}	E_S	Return to scale
1	89.51	92.23	97	Additive
2	87.63	90.7	96	Additive
3	100	100	100	Fixed
4	91.12	93.15	97	Additive
5	79.7	81.3	98	Additive
6	92.23	100	92	Additive
7	79.66	83.8	94	Additive
8	76.82	79.15	97	Additive
9	100	100	100	Fixed
10	90.2	97.7	92	Additive
11	83.57	85.23	98	Additive
12	91.12	93.7	97	Additive
13	89.31	100	89	Additive
14	83.43	87.7	95	Additive
15	92.82	95.2	97	Additive
16	92.82	95.2	97	Additive
17	100	100	100	Fixed
18	100	100	100	Fixed
19	85.56	87.43	97	Additive
20	79.49	82.12	97	Additive
21	83.39	100	83	Additive
22	100	100	100	Fixed
23	82.81	84.4	98	Additive
24	76.23	78.1	97	Additive
25	85.12	87.2	97	Additive
Average	87.97	91.18	96	-

consumption to stand on the efficiency partition line. The average share of each input in decreasing energy consumption for wheat farms is illustrated in Figure 3(transportation share was not considered as it was less than one).

DISCUSSION

In this research, energy consumption for seed, fertilizers and chemicals in wheat production were 39875.2 MJha^{-1} and the total mean energy used in various farm steps during wheat production was 58367.69 MJ/ha. In a similar study (Houshyar et al., 2010), total energy inputs for wheat production in Fars Province of Iran were reported to be 38589 MJha^{-1}. The results showed that the most energy consuming input for wheat production in the different farms investigated was fertilizer and chemicals. Similar results were found in the literature that the highest energy item was diesel fuel in agricultural crops production (Singh, 2002; Faraj, 2007; Hassanzadeh and Mazaheri, 1996; Singh et al., 2004). The energy equivalent of fuel consumption was placed second among the energy inputs and constituted 14% of the total energy input. From Table 2, it is shown that transportation is the least demanding energy input for wheat production with 980.34 MJha^{-1}.

The energy ratio in the production of wheat in this area was found to be 0.912; showing that output energy of wheat is obtained about 0.9 times greater than total input energy. Also, energy productivity was calculated as 0.052 kg MJ^{-1}. Energy ratio and energy productivity are integrative indices indicating the potential environmental impacts of crop production (Khan et al., 2009). The energy ratio for some agricultural crop productions was reported as 2.8 for wheat, 4.8 for cotton, 3.8 for maize, 1.5 for sesame (Canakci et al., 2005), and 2.86 for barley (Ghasemi et al., 2010). The results of DEA showed that the technical, pure technical and scale efficiency scores for wheat were 0.8797, 0.9118 and 0.96, respectively (Table 5). On an average, the total input energy could be reduced by 15% without reducing the wheat yield from its present level by adopting the recommendations based on the present study.

Based on the literature, the technical efficiency scores of 0.75 for tomato, 0.81 for asparagus production (Iráizoz

Table 6. Slack and surplus energy consumption in each of wheat farms with CCR model ($MJha^{-1}$).

DMU	Efficiency	SFC	Transportation	Human	Irrigation	Machinery	Fuel
1	89.51	23178	0	0	3865	0	4640
2	87.63	22891	223	1200	0	1312	6100
3	100	0	0	0	0	0	0
4	91.12	18900	0	103	0	1030	4700
5	79.7	23189	0	900	2678	0	5123
6	92.23	12134	0	0	0	1673	4534
7	79.6	23908	108	0	3780	1200	2800
8	76.82	23267	214	0	3180	1900	5612
9	100	0	0	0	0	0	0
10	90.2	20012	0	0	3124	0	5100
11	83.57	21812	145	167	3780	0	4512
12	89.31	25314	360	0	2890	0	1200
13	92.82	11512	0	200	1289	0	2670
14	83.43	20245	351	0	2780	0	5231
15	79.6	22679	241	0	1907	1450	5180
16	92.82	11512	0	200	1289	1413	0
17	100	0	0	0	0	0	0
18	100	0	0	0	0	0	0
19	85.56	20314	0	190	2134	1129	4512
20	79.49	25671	314	0	2280	1280	5500
21	83.39	19345	0	0	3125	0	5389
22	100	0	0	0	0	0	0
23	82.81	22289	0	0	2700	0	4341
24	76.23	27156	0	120	2080	0	3490
25	85.12	19730	146	0	3709	1670	4123

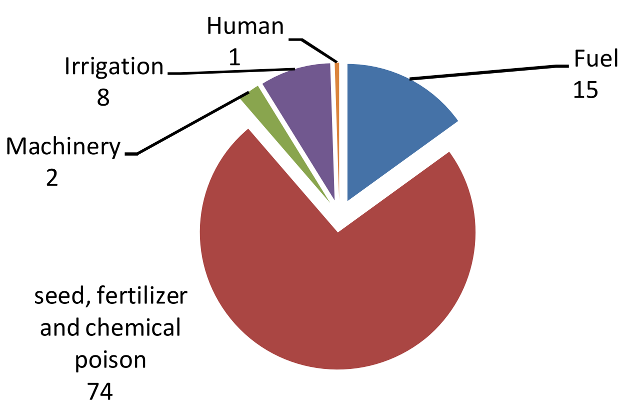

Figure 3. Energy saved via each input with CCR Input Oriented in wheat farms.

et al., 2003) and 0.782 for pig farming (Galanopoulos et al., 2006) were reported. Also, Chauhan et al. (2006) applied DEA approach to determine the efficiencies of farmers with regard to energy use in paddy production in India. In their study, the technical, pure technical and scale efficiencies of farmers were estimated as 0.83, 0.92 and 0.77, respectively. Fertilizer and chemical poison carries relatively higher weights in the distribution of the virtual inputs for truly efficient producers. If inefficient producers would pay more attention towards this source, they would improve their energy productivity. Similar results were found by Omid et al. (2011) for cucumber production in Tehran Province of Iran. Chauhan et al. (2006) reported that the contribution of fertilizer and diesel energy inputs from total saving energy in paddy production were 33 and 24%, respectively. Mousavi-Avval et al. (2011) reported that in optimization of energy use for apple production, the contribution of electrical energy from total saving energy was the highest; also, fertilizer and diesel fuel had relatively high contributions.

Energy input in various operations with time and duration can be considered separately for a DEA type study. Such a study will help to pinpoint more precisely the agricultural practices at the operation level that make a producer efficient. Results show DEA is very suitable to analyze these data and extract many distinctive features of their practices. DEA has helped in segregating efficient agricultural units from inefficient agricultural units. It has also helped in finding the wasteful uses of energy by inefficient units and ranking energy sources by using the distribution of virtual inputs. The practices followed by the truly efficient producers form a set of recommendations in terms of efficient operating practices for the inefficient ones.

Conclusion

This paper describes the application of DEA as a non-parametric method to the study, for improving the energy use in the wheat production in the Khozestan Province of Iran. This technique allows the determination of the best practice farms and can also provide helpful insights for farm management. DEA has helped in segregating efficient farmers from inefficient farmers. It has also helped in finding the wasteful uses of energy by inefficient farmers, ranking efficient farmers by using the CCR and BCC models and ranking energy sources by using technical, pure technical and scale efficiency. The results revealed that wheat production depends mainly on fertilizer, chemicals and fuel energy inputs.

In this study, the mean of technical efficiency of inefficient units was estimated as 85% according to the constant return to scale model. In other words, 15% of all of the resources can be saved by increasing the efficiency of these units. DEA optimizes the performance measure of each farm or decision making unit (DMU). Specifically, the DEA was used to compare the performance of each DMU in the region of increasing, constant or decreasing return to scale in multiple-inputs situations. The CCR model helped us to decompose the pure TE into the overall TE and SE components, thereby allowing investigating the scale effects.

REFERENCES

Anonymous (2010). Annual agricultural statistics. Ministry of Jihad-e-Agriculture of Iran.

Anonymous. (2009). Fertilizer use by crop in the Islamic Republic of Iran, www.fao.org.

Anonymous. (2008). Annual agriculture statistics, Ministry of agriculture-Jihad of Iran, www.maj.ir.

Banaeian N, Zangeneh M, Omid M (2010). Energy use efficiency for walnut producers using Data Envelopment Analysis (DEA). Australian J. Crop Sci., 4(5): 359-362.

Banaeian N, Omid M, Ahmadi H (2011). Application of Data Envelopment Analysis to Evaluate Efficiency of Commercial Greenhouse Strawberry. Res. J. Appl. Sci. Eng. Technol., 3(3): 185-193.

Banker RD, Charnes A, Cooper WW (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage. Sci., 30(3): 1078-1092.

Canakci A, Akinci I (2006). Energy use pattern analyses of greenhouse vegetable production. Energy, 31(8-9):1243-56.

Charnes AW, Copper W, Rhodes E (1984). measuring the efficiency of decision marking units. Eur. J. Oper. Res., 2(1): 429-444.

Chaudhary VP, Gangwar B, Pandey DK (2006). Auditing of energy use and output of different cropping systems in India, Agricultural Engineering international, the CIGR j EE 05001.

Chauhan NS, Mohapatra PKJ, Pandey KP (2006). Improving energy productivity in paddy production through benchmarking - an application of data envelopment analysis. Energy Conversion Manage., 47: 1063-1085.

Cochran-William G (1977). Sampling Techniques, Third Edition. Emami meibodi A (2000). Measurement principles of efficiency and performance. Institute of Business Studies and Research Press.

Faraj Y (2007). A research on current status of farm mechanization and energy indices in Dasht-Abbas plain and provision of guidelines towards development in Iran, Msc Thesis, Faculty of Agriculture, University of Tabriz, Iran.

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

Ghasemi Mobtaker H, Keyhani A, Mohammadi A, Rafiee S, Akram A (2010). Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agriculture, Ecosystems & Environment, 137(3-4): 367-372.

Gheisari K, Mehrno H, Jafari AR (2007). A general review of envelopment analysis of phase data. The Scientific Publishing Center, Islamic Azad University of Qazvin.

Gochebeyg F, Omid M, Ahmadi H, Delshad D (2009). evaluation and development of efficient usage of energy recourses in cucumber production in green houses in Province of Tehran, by using data envelopment analysis, The 6th national conference of mechanic and mechanization of agricultural machinery, Agriculture and natural resources faculty, University of Tehran.

Hassanzadeh GT, Mazaheri DA (1996). Evaluation of energy balance in three farms of wheat, potato and rice in Falavarjan region of Isfahan Abstract papers of 4th Congress on Agronomics and Plant Breeding of Iran.

Houshyar E, Sheikh Davoodi MJ, Nassiri SM (2010). Energy efficiency for wheat production using data envelopment analysis (DEA) technique. J. Agric. Technol., 6(4): 663-672.

Iraizoz B, Rapun M, and Zabaleta I (2003). Assessing the technical efficiency of horticultural production in Navarra, Spain. Agric. Syst., 78: 387-403.

Kaltschmittn M, Reinhardt GA, Stelzer T (1997). Life cycle analysis of befouls under different environmental aspects. Biomass and Bio energy, 12(2): 121-134.

Karkacıer O, Goktolga ZG (2005). Input-output analysis of energy use in agriculture. Energy Conversion Manage., 46(9-10): 1513- 1521.

Khan S, Khan MA, Hanjra MA, Mu J (2009). Pathways to reduce the environmental footprints of water and energy inputs in food production, Food Policy, 34: 141-149

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

Mandal KG, Saha KPP, Ghosh KK, Hati M, Bandyopadhyay KK (2002). Bio energy and economic analysis of soybean-based crop production systems in central India. Biomass Bioenergy, 23(5): 337-345.

Mohammadi A (2008). Measuring the poultry generation centers by using data envelopment analysis (case study: Province of Fars). Agricultural economic and development Press, 16(3): 89-116.

Mohammadi A, Tabatabaeefar A, Shahin Sh, Rafiee Sh, Keyhani A (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Conversion and Manage., 49: 3566-3570.

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

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

Nassiri SM, Singh S (2010). A comparative study of parametric and non-parametric energy efficiency in paddy production. J. Agric. Sci. Technol., 12: 379-389.

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

Samavatian N, Rafii Sh, Mobli M (2009). Evaluation of developing the energy consumption for garlic production by using data envelopment analysis. The 6th national conference of mechanic and mechanization of agricultural machinery, Agriculture and natural resources faculty, University of Tehran.

Shafiq M, Rehman T (2000). The extent of resource use inefficiencies in cotton production in Pakistan's Punjab: an application of Data Envelopment Analysis. Agric. Econ., 22: 321-330.

Sharma KR, Leung PS, Zaleski HM (1999). Technical, locative and economic efficiencies in swine production in Hawaii: A comparison of

parametric and nonparametric approaches. Agric. Econ., 20: 23-35.
Singh G, Singh S, Singh I (2004). Optimization of energy input for wheat crop in Punjab. Energy Conversion Manage., 45: 453-465.
Singh JM (2002). On farm energy use pattern in different cropping system in Haryana, India, Thesis for Master of Science in sustainable energy systems and management. University of Flensburg, Germany.
Singh H, Mishra D, Nahar NM (2002). Energy use pattern in production agriculture of a typical village in arid zone, India – part-I, Energy Conversion Manage., 43(16): 2275-2276.
Yaldiz O, Ozkan HH, Zeren Y, Bascetincelik A (1993). Energy usage in production of field crops in Turkey. *5th* International Congress on Mechanization and Energy Use in Agriculture, 11 – 14-Oct. Kusadasi, Turkey.
Yong T, Chunweki K (2003). A hierarchical AHP/DEA methodology for the facilities layout design problem. Eur. J. Oper. Res., 147(2): 128-136.