Modeling of wheat yield and sensitivity analysis based on energy inputs for three years in Abyek town, Ghazvin, Iran

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Abstract: To get a proper energy consumption pattern and an increase in energy productivity, determining a relationship between energy inputs and outputs is necessary. In this study, the equivalent energy of inputs and outputs data used in wheat production in Abyek town of Ghazvin province, Iran was collected from farmers over three years. The energy ratio was obtained as 2.11, 2.08 and 2.03 and energy productivity was obtained as 0.15, 0.14 and 0.14 (kg MJ^{-1}) for 2010, 2009 and 2008, respectively. It was found that the contributions of indirect and non-renewable energies on wheat yield were more than the impacts of direct and renewable energies. To determine the effects of energy inputs on wheat yield, the Cobb–Douglas production function was used. Model 1 was composed of individual energy inputs: labor, machinery, electricity, diesel fuel, water for irrigation, fertilizer, chemicals and seed energies In Model 2 energy inputs divided to direct and indirect energies and in Model 3 they divided to renewable and non-renewable energies. The R^2 values in all three models were more than 0.98 and showed that the models can estimate well. The sensitivity analysis results for Model I showed that the major marginal physical productivities (MPPs) were water for irrigation, human labor and water for irrigation in 2010, 2009 and 2008, respectively. In Model II, the major MPP belongs to for renewable energy in the same years.

Keywords: energy consumption pattern, Cobb-Dauglas, marginal physical productivity, renewable, return to scale

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1 Introduction

Energy use is more important in sustainable agricultural practices. Due to decreasing of some energy resources and non-renewability of them, finding a solution to reduce energy consumption per production unit seems to be essential to reach the sustainable development and to save interest of future generation. Productivity of energy consumption can lead to sustainable development purposes. Effective application of resources is vital in terms of production, productivity, competitive agriculture and sustainability of rural life. Growth and progression of used technology and production level in agriculture affect on amount of energy consumption per unit area (Hatirli et al., 2006). Thus, determining the relation between energy inputs and outputs in crops production can be an effective step to find inputs that consume more energy and to find

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solutions for reducing energy consumption per area. Also, it can be effective to get the high energy productivity. Decreasing energy consumption by introducing advanced technology and correct usage of any inputs will reduce costs for crop production. Indeed, energy surveying enable researchers to calculate energy ratio and obtain the energy consumption pattern. Different forms of energy are used in agricultural crops production and many factors can affect amount of energy consumption. Calculation of energy inputs in agricultural section is difficult rather than industrial sections because there are lots of factors that affect crop productions in agricultural sector (Mohammadi and Omid, 2010; Yaldiz et al., 1993). The main purposes in agricultural production are to increase yield and decrease costs. The energy consumption pattern and contribution of energy inputs is different with regard to agricultural systems, growth season and cultivating conditions. Thus, attention to relationship of energy inputs and yield using functional form is very important (Hatirli et al., 2006). Various researches have conducted their investigations in this context. Some of them have concentrated on energy consumption in greenhouse productions (Khakbazan, 2000; Ozkan et al., 2004b; Hatirli et al., 2006; Mohammadi and Omid, 2010; Banaeian et al., 2011). Also, some works have been done on agricultural crops. Nassiri and Singh (2009) have conducted a comparative study on energy productivity of rice in India. Ghasemi et al. (2010) obtained the economic model of alfalfa cost inputs and yield using Cobb-Douglas production function in Hamedan province of Iran. Mobtaker et al. (2010) were conducted the sensitivity analysis of energy inputs for barley production. Ghasemi et al. (2011) were compared Energy consumption in alfalfa production between two irrigation systems. Yousefi and Mohammadi (2011) were conducted economical analysis and energy use efficiency in alfalfa production systems. Wide range of arable land is devoted to wheat cultivation in Iran, so the wheat is one of the strategic crops in this country. The average amount of irrigated wheat production in Ghazvin province of Iran was 236,499 tonne in 2009 harvested from 52,702 ha of agricultural lands (Ananymous, 2009).

The objectives of this study were: 1- to obtain relationship between energy inputs and wheat yield for three years of 2008, 2009 and 2010 in Abyek town of Ghazvin province in Iran, 2- to sensitivity analysis of energy inputs on wheat yield. Results may specify the impact of each input and can serve as an alternative to designers for offering of energy consumption pattern solution.

2 Materials and methods

The study was conducted in part of Abyek town of Ghazvin province, Iran between 35º 54' 55" and 36º 01' 41" northern latitude and 50º 24' 25" to 50 º 34' 40" eastern longitudes. This study carried out for winter wheat fields in an area including 8,171.217 ha. The required information was collected from the questionnaires filled in through face-to-face interviews. The Yamane equation (Equation (1)) was used to obtain the number of required questionnaires (Yamane, 1967):

$$n = \frac{(\sum N_h S_h)}{N^2 D^2 + \sum N_h S_h^2} \qquad (1)$$

where, n is the number of required questionnaires; N is the number of holdings in target population; N_h is the number of the population in the h stratification; S_h is the standard deviation in the h stratification; S^2_h is the variance of h stratification, d is the precision where $(\bar{x} - \bar{X})$; z is the reliability coefficient (1.96 which represents the 95% reliability), and $D^2 = d^2/z^2$. For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used. The size of 70 was obtained as number of questionnaires. Required information have been taken from 70 farmers using simple randomize sampling method for three years of 2008, 2009 and 2010 in Abyek town of Ghazvin province, Iran. Practices and required operation, approximate calendar of each operation and number of performance for all three years is represented in Table 1.

Table 2 shows the unit and energy equivalent for each input and output in crop production. Also, the reference of each energy equivalent is shown.

Table 1 Time of required operation for wheat production in Abyek town

Calendar and other specification	Practices and required operations
20 Sept. – 15 Nov.	Land preparation period
285 MF 75 hp, 399 MF 110 hp	tractor used for Land preparation
Moldboard, Disc harrows, Land leveler	tillage type
2	Average number of tillage
20 Oct.-20 Nov.	Planting period
Nov. – Apr.	Fertilization period
1.8	Average number of fertilization
Nov. – Mar. – Apr. – May.	Irrigation period
4.8	Average number of irrigation
Mar. – Apr.	Spraying period
2	Average number of spraying
1 Jul.-30 Jul.	Harvesting period

Table 2 Amount of input and output and their energy equivalent

Input-output (unit)	Energy equivalent (MJ/unit)	references
Inputs:		
Labor (h)	1.96	Esengun et al., 2007b
Machinery (h)	62.70	Singh, 2002
Electricity (kWh)	3.6	Ghorbani et al., 2011
Diesel fuel (L)	56.31	Singh, 2002
Water for irrigation (m^3)	1.02	Singh et al., 1998; Acaroglu, 1998
Nitrate (kg)	66.14	Shrestha, 2002
Phosphate (kg)	12.44	Shrestha, 2002
Potassium (kg)	11.15	Shrestha, 2002
Chemicals (kg)	120	Singh, 2002
Seed (kg)	14.7	Ozkan, 2004a
Outputs:		
Wheat (kg)	14.7	Ozkan, 2004a
Straw (kg)	12.5	Ozkan, 2004a

To calculate some energy indices, following Equation (2), Equation (3), Equation (4) and Equation (5) was used (Mandal et al., 2002; Mohammadi et al., 2010):

$$EUE(ER) = \frac{E_o(\text{MJ ha}^{-1})}{E_i(\text{MJ ha}^{-1})} \tag{2}$$

$$EP(\text{kg MJ}^{-1}) = \frac{Y(\text{kg ha}^{-1})}{E_i(\text{MJ ha}^{-1})} \tag{3}$$

$$SE(\text{MJ kg}^{-1}) = \frac{1}{EP} \tag{4}$$

$$NE(\text{MJ ha}^{-1}) = E_o(\text{MJ ha}^{-1}) - E_i(\text{MJ ha}^{-1}) \tag{5}$$

where, *ER* (*EUE*) denotes dimensionless energy ratio (energy use efficiency); E_o and E_i are energy output and input (MJ ha^{-1}), respectively; *EP* is energy productivity (kg MJ^{-1}); *Y* is wheat yield (kg ha^{-1}); *SE* is specific energy (MJ kg^{-1}) and *NE* is net energy (MJ ha^{-1}).

2.1 Estimation function

The one of equations that expresses the relationship between inputs and outputs is Cobb-Douglas equation. Cobb–Douglas production function showed better estimates in terms of statistical significance and expected signs of parameters in studies done by Singh et al. (2002) and Mohammadi and Omid (2010). The Cobb–Douglas production function (Equation (6)) is expressed as:

$$Y = f(x)\exp(u) \tag{6}$$

In other words (Equation (7)):

$$\ln Y_i = \alpha_0 + \sum_{j=1}^{m} \alpha_i \ln X_{ij} + e_i$$

$$i = 1, 2, \ldots, n \text{ and } j = 1, 2, \ldots, m \tag{7}$$

where, Y_i denotes the yield of the ith farmer; α_i coefficients of effective energy inputs; *j* the number of energy inputs; X_{ij} the vector of inputs used in the crop production process, α_0 the constant term and e_i is the error term. We can expand Equation (7) with regard to effective energy inputs on crop production such as human labor (X_1), machinery (X_2), electricity (X_3), diesel fuel (X_4), water for irrigation (X_5), fertilizer (X_6), chemicals (X_7), seeds (X_8). It can been written as Equation (8):

$$\ln Y_i = \alpha_1 \ln X_{i1} + \alpha_2 \ln X_{i2} + \cdots + \alpha_j \ln X_{ij} + e_i \tag{8}$$

Total energy input (E_i) can express as composition of direct energy (DE) and indirect energy (IDE) and also renewable energy (RE) and non-renewable energy (NRE). DE consists of human labor, diesel fuel, electricity, and water for irrigation energy and IDE includes of machinery, fertilizer, seeds and chemicals energy. In other hands, human labor, seed and water for irrigation forms RE and machinery, diesel fuel, fertilizer, chemicals and electricity form NRE. Thus, to obtain coefficients of DE, IDE, RE and NRE used in production process, we can express the Equation (8) as Equation (9) and Equation (10):

$$\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i \tag{9}$$

$$\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \tag{10}$$

In Equation (9), β_1 and β_2 are the coefficients of DE and IDE and γ_1 and γ_2 are the coefficients of *RE* and NRE in Equation (10), too.

2.2 Sensitivity analysis

Marginal physical productivity (MPP) technique based on response coefficient of inputs was used for sensitivity analysis of each energy input on yield. In real, the MPP of a factor input points the change in the output with a unit change in the factor input in question, keeping all factors constant at geometric mean level (Singh et al., 2004; Heidari and Omid, 2011). The MPP (Equation 11) of each input was computed using regression coefficient of energy input as given by Manes and Singh (2005):

$$MPP(X_i) = \frac{GM(Y)}{GM(X_i)} \times \alpha_i \tag{11}$$

where, $MPP(X_i)$ is the MPP of ith input; α_i, regression coefficient of ith input; $GM(Y)$, geometric mean of yield; and $GM(X_i)$, geometric mean of ith input on per hectare basis (Havil, 2003).

The returns to scale (RTS) refer to increasing or decreasing efficiencies based on size of change (Heidari and Omid, 2011). There are three categories for the change in production in response to proportionate changes in all inputs: 1- A constant RTS occurs when a doubling of input results in a doubling of output and it is often abbreviated CRS. 2- An increasing RTS or IRS occurs when a given percentage increases in all inputs, leads to a larger percentage increase in output. 3- Decreasing RTS or DRS exists when a given percentage increase in all inputs, leads to a smaller percentage increase in output. In this paper the RTS values for all models were determined by gathering the elasticity, derived in the form of regression coefficients in the Cobb-Douglas production function. If the sum is more than, equal to, or less than unity it implys that there are IRS, CRS, or DRS, respectively (Singh et al., 2004; Heidari and Omid, 2011). The used software to obtain and analysis the results in this study were the SPSS 17 and Excel 2007.

3 Results and discussion

In the study, the average size of farms was 14.64 ha for wheat production and the entire field was irrigated.

3.1 Input–output energy analysis

The amount of inputs and outputs used in wheat production in the study area, their equivalent energy and percentage of each energy input in to total energy input for years of 2008, 2009 and 2010 are shown in Table 3. In this table, the amount of consumed fuel has been used for machines and some engines of water wells. As is seen in this table, fertilizer energy spent the most percentage of total energy input followed by fuel and electricity in this region for all three years. At first, it seems that farmers should try to reduce fertilizer and fuel consumptions and fuel losses in this region until the energy efficiency and energy productivity increases with total energy input reduction. Seeds, water for irrigation, machinery, chemicals and human labor had less share of

Table 3 Amount of inputs and output and their equivalent energy in three years

Type of energy (unit)	Quantity (unit / ha)			Equivalent energy (MJ ha^{-1})			Percentage of the total energy input (%)		
Year	2008	2009	2010	2008	2009	2010	2008	2009	2010
Inputs:									
Labor (h)	313.53	349.43	361.06	614.53	684.88	707.69	0.91	1.02	1.06
Machinery (h)	23.93	26.52	27.07	1500.59	1662.85	1697.46	2.23	2.49	2.53
Electricity (kWh)	3769.52	3892.92	3726.97	13570.25	14014.49	13417.11	20.13	21.02	20.02
Diesel fuel (L)	252.28	259.48	61.70	14205.61	14611.55	14736.39	21.07	21.91	21.99
Irrigation water (m^3)	1777.20	1853.14	795.82	1812.74	1890.21	1831.74	2.68	2.86	2.73
Total fertilizer (kg)	867.67	813.18	828.12	31670.59	29747.58	30266.11	46.98	44.62	45.16
Nitrogen (kg)	393.50	370	376.23	26026.09	24471.80	24883.98	38.60	36.71	37.13
Phosphate (kg)	277.17	259.21	266.38	3447.95	3224.53	3313.72	5.10	4.84	4.94
Potassium (kg)	197	183.97	185.51	2196.55	2051.25	2068.41	3.28	3.07	3.09
Chemicals (kg)	7.79	7.84	10.12	935	940.95	1213.91	1.38	1.41	1.81
Seed (kg)	211.33	211.74	214.20	3106.6	3112.67	3148.78	4.60	4.66	4.69
Outputs:									
Wheat (kg)	5966.67	5991.75	6010.15	87710	88078.67	88349.13	69.36	68.41	67.69
Straw (kg)	3100	3253.97	3373.91	38750	40674.60	42173.91	30.64	31.59	32.31

total energy input respectively. From this table, it was concluded that the energy consumption procedure at year of 2010, 2009 and 2008 for wheat production was almost similar. Figure 1 shows the share of each energy input in wheat production and Figure 2 shows the share of other forms of energy as DE, IDE, RE and NRE.

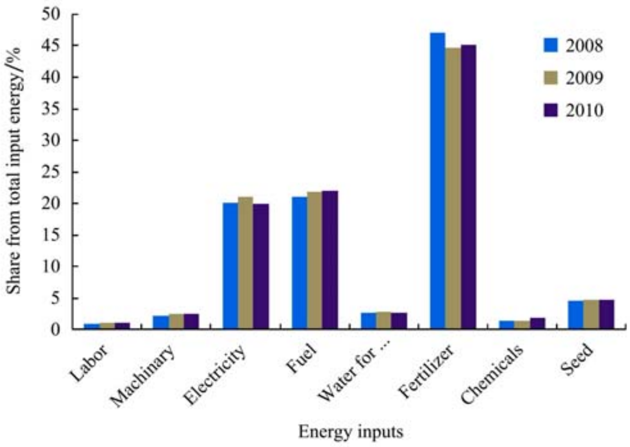

Figure 1 Share of each energy input in wheat production

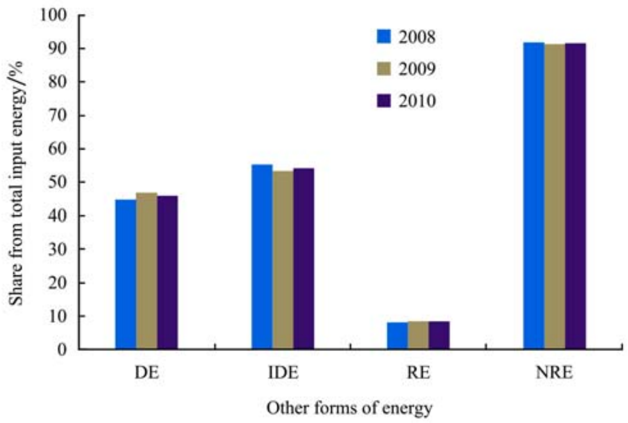

Figure 2 Share of other forms of energy in wheat production

The energy indices and amount of direct, indirect, renewable and non-renewable energies for years of 2008, 2009 and 2010 in Abyek is shown in Table 4.

The average ER (EUE) in this research was calculated as 2.03, 2.08, and 2.11 in the years 2008, 2009 and 2010 respectively. It means that ER (EUE) has increased little by 2010. In Turkey, it was reported 2.8 for wheat by Canakci et al. (2005). Singh et al. (2007) calculated ER as 2.9, 4.0, 4.2 and 5.2 at different locations in India. Shahan et al. (2008) repotted ER as 1.97 for wheat in Ardabil province. Then, the average EP was calculated and obtained 0.14, 0.14 and 0.15 kg MJ^{-1} in the years 2008, 2009 and 2010 respectively. This means that 0.15 kg of wheat output was obtained per consumed unit energy and it was the same for all of three years in Abyek. This index was 1.0 for stake-tomato (Esengun et al., 2007a), 0.06 for cotton (Yilmaz et al., 2005) and 1.53 for sugar beet (Erdal et al., 2007). The average NE of wheat production was about 59,044, 62088 and 63,504 MJ ha^{-1} for 2008, 2009 and 2010 respectively. It means that NE has increased by 2010.

Table 4 Amounts of other forms of consumed energy in wheat production in three years

Item	Value			Percentage (%)		
	2008	2009	2010	2008	2009	2010
E_i (MJ ha^{-1})	67415.91	66665.17	67019.19	100	100	100
- DE [a]	30203.13	31201.13	30692.93	44.80	46.80	45.79
- IDE [b]	37212.78	35464.05	36326.26	55.20	53.19	54.20
- RE [c]	5533.87	5687.75	5688.21	8.21	8.53	8.49
- NRE [d]	61882.04	60977.42	61330.98	91.79	91.46	91.51
E_O (MJ ha^{-1})	126460	128753.27	130523.04	-	-	-
Y_t (kg ha-1)	9066.67	9245.71	9384.06	-	-	-
ER (EUE)	2.03	2.08	2.11	-	-	-
SE (MJ kg^{-1})	8.67	8.41	8.12	-	-	-
EP (kg MJ^{-1})	0.14	0.14	0.15	-	-	-
NE (MJ ha^{-1})	59044.09	62088.09	63503.85	-	-	-

Note: a: Includes human labor, diesel fuel, electricity and water for irrigation energies.
b: Includes machinery, fertilizer, seeds and chemicals energies.
c: Includes human labor, seed and water for irrigation energies.
d: machinery, diesel fuel, fertilizer, chemicals and electricity energies.

The E_i form about 45% and 55% of total input energy as DE and IDE for 2008, respectively. About 47% and 53% of total input energy was as DE and IDE, respectively in 2009. Finally, about 46% and 54% of total input energy was as DE and IDE, respectively in 2010. The E_i forms about 8.2% and 91.8% of total input energy as RE and NRE, respectively in 2008. This shows that more percentage of energy consumed to wheat production is non-renewable and they haven't been replaced. Similarly, about 8.5% and 91.5% of total input energy belongs to RE and NRE in 2009 respectively. About 8.5% and 91.5% of total input energy belongs to RE and NRE in 2010, respectively.

3.2 Econometric model estimation of wheat production

To know the effects of each energy input on yield and to improve any incorrect pattern of energy consumption in crop production, we used the Cobb–Douglas production function to estimate the energy inputs and wheat yield relationship. Wheat yield as a dependent variable was assumed to be a function of above mentioned energy inputs (independent variables). Regression results for Equation (9), Equation (10) and Equation (11) as Models I, II and III are presented, respectively. Results showed that the impacts of each input differ in constitution production level in wheat production. Some energy inputs had negative effect and some of energy inputs had positive impact on wheat yield. The Durbin–Watson test was tested for data autocorrelation (Hatirli et a., 2010). The Durbin-Watson values in all three Models and years was bigger than 1.28. These results are acceptable with regard to number of variables, number of observations, absence of intercept, lower and upper bounds and 1% Significance Level.

3.2.1 Results of Model I

In the year 2008, the R^2 was 0.999. The Durbin–Watson value was obtained as 1.39 and it was concluded that there is no autocorrelation in the estimated model at 1% significant level. In Table 5, the values of coefficients (α_i), t-student (t) and marginal physical productivity (MPP) have been shown. The machinery, electricity, and fertilizer energies had negative effects on wheat yield as (-0.28), (-0.32) and (-0.16), respectively. But machinery and fertilizer impacts were not significant. Also the human labor (0.06), diesel fuel (0.91), water for irrigation (0.42), chemicals (0.05) and seeds (0.38) had positive effects on wheat yield. However, the impact of human labor, chemicals and seeds was not significant. The highest impact (0.91) was for diesel fuel. This impact was significant at 1% level. The second important input was water for irrigation with coefficient of 0.42 that was significant at 5% level. But the impact of seeds with coefficient of 0.38 was not significant.

In the year 2009, the R^2 was as 0.999 and Durbin–Watson value was obtained 1.32. As is shown in Table 5, machinery (-0.34), electricity (-0.25), and fertilizer (-0.25) energies all had negative effects on yield. This means that by increase in the machinery, fertilizer and electricity energies the amount of output yield decreases at same condition and their effects were significant. The human labor (0.13) impact was positive. Also diesel fuel (0.95), water for irrigation (0.24), chemicals (0.02) and seeds (0.57) had positive effects. This means that by increase in the human labor, diesel fuel, water for irrigation, chemicals and seed energy input, the amount of output yield decreases under the same condition. However, the impact of human labor, water for irrigation and chemicals was not significant, but the impact of diesel fuel and seeds was significant in this year. Diesel fuel had the highest impact (0.95) followed by seeds and water for irrigation.

Table 5 The estimation results for Model I and their coefficients

Model I: $\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + \alpha_8 \ln X_8 + e_i$

Year	2008			2009			2010		
Independent variables	α_i	t	MPP	α_i	t	MPP	α_i	t	MPP
Human labor	0.06	0.45 ns	0.70	0.13	1.14 ns	1.36	-0.12	-1.27 ns	-1.25
Machinery	-0.28	-1.70 ns	-1.24	-0.34	-2.61**	-1.36	-0.16	-1.52 ns	-0.65
Electricity	-0.32	-3.64 *	-0.20	-0.25	-3.83*	-0.15	-0.33	-6.58*	-0.23
Diesel fuel	0.91	4.01 *	0.37	0.95	5.62*	0.38	0.97	6.52*	0.39
Water for irrigation	0.42	2.14 **	1.39	0.24	1.52 ns	0.76	0.46	3.49*	1.54
Total fertilizer	-0.16	-1.09 ns	-0.03	-0.25	-2.29**	-0.05	-0.24	-2.67**	-0.05
Chemicals	0.05	0.82 ns	0.40	0.02	0.76 ns	0.17	0.01	0.01 ns	0.07
Seed	0.38	1.57 ns	0.71	0.57	2.89*	1.05	0.47	2.78*	0.88
R^2	0.999	-	-	0.999	-		0.999	-	-
Durbin-Watson	1.39	-	-	1.32	-	-	1.28	-	-
RTS	1.06	-	-	1.07	-	-	1.06	-	-

Note: * significance at 1% level; ** significant at 5% level; and ns not significant

In the year 2010, the R^2 was 0.999 and the Durbin–Watson value was obtained as 1.28. As is shown in Table 5, the human labor (-0.12), machinery (-0.16), electricity (-0.33), and fertilizer (-0.24) energy had negative effects on yield. However, the impacts of human labor and machinery energies were not significant. Also diesel fuel (0.97), water for irrigation (0.46), chemical (0.01) and seeds (0.47) had positive effects. This means that by increase in the diesel fuel, water for irrigation, chemicals and seed energy input, the amount of output yield increases at same condition. However, the impact of chemicals was not significant. Diesel fuel had the highest impact (0.97) rather than other inputs and was significant at 1% level. The second important input was water for irrigation with 0.46 coefficient followed by seed with 0.47 coefficient.

3.2.2 Results of Model II

The estimation results of Model II have been illustrated in Table 6. As is seen in this table, in the year 2008, the R^2 and Durbin-Watson values were 0.997 and 1.42 respectively, and it was found that there was no autocorrelation in the estimated model at 1% significant level. The values of coefficients (β_i), t-student (t) and MPP have been shown.

Table 6 Estimation results for Model II and their coefficients

Model II: $\ln Y_i = \beta_1 \ln DE_1 + \beta_2 \ln IDE_2 + e_i$

year	2008			2009			2010		
Independent variables	β_i	t	MPP	β_i	t	MPP	β_i	t	MPP
DE	-0.03	-0.20 ns	-0.01	0.26	1.93 **	0.05	0.05	0.41 ns	0.01
IDE	0.89	5.92 *	0.14	0.61	4.63 *	0.10	0.82	7.42*	0.14
R^2	0.998	-	-	0.997	-	-	0.998	-	-
Durbin-Watson	1.38	-	-	1.42	-	-	1.35	-	-
RTS	0.86	-	-	0.87	-	-	0.87	-	-

Note: * significance at 1% level; ** significant at 5% level; and ns not significant

The impacts of DE and IDE on yield shows that DE has little effect (-0.03) rather than IDE (0.89) and the effect of DE was not significant but the effect of IDE was significant at 5% level. According to this, the impact of indirect energy was more than direct energy on yield of greenhouse tomato and kiwifruit production, respectively (Hatirli et al.,2006; Mohammadi et al., 2010). In the year 2009, the R^2 and Durbin-Watson values were 0.997 and 1.42 respectively. The coefficients of DE and IDE in Model II were 0.26 and 0.61 respectively. The effect of DE was significant in 5% level and the effect of IDE was significant at 1% level. In the year 2010, the R^2 and Durbin-Watson values were 0.998 and 1.35 respectively. The DE (0.05) and IDE (0.82) had positive effect. The effect of DE was not significant, but the effect of IDE was significant at 1% level.

3.2.3 Result of Model III

The estimation results of Model III have been illustrated in Table 7. In the year 2008, the R^2 and Durbin-Watson values were 0.998 and 1.48 respectively. The values of coefficients (γ_i), t-student (t) and MPP have been shown. The RE had positive (1.10) effect on wheat yield while NRE had negative (-0.04) effect. The effect of RE was significant at 1% level but the effect of NRE was not significant. Similar results have been reported that the contribution of non-renewable energy to the output level was more than renewable energy (Heidari and Omid, 2011). In the year 2009, the R^2 and Durbin-Watson values were 0.999 and 1.34 respectively. The RE and NRE had positive (1.14) and negative (-0.07) effects on wheat yield respectively. The effect of RE was not significant but the effect of NRE was significant at 1% level. In the year 2010 similar to 2008 and 2009, the RE had positive (1.10) effect on wheat yield but NRE had negative (-0.04) effect. The R^2 and Durbin-Watson value in this model was 0.999 and 1.42 respectively.

Table 7 The estimation results for Model III and their coefficients

Model 3: $\ln Y_i = \gamma_1 \ln X_1 + \gamma_2 \ln X_2 + e_i$

year	2008			2009			2010		
Independent variables	γ_i	t	*MPP*	γ_i	t	*MPP*	γ_i	t	*MPP*
RE	1.08	6.21 *	1.14	1.14	6.91 ns	1.16	1.10	7.43 *	1.15
NRE	-0.02	-0.15 ns	-0.002	-0.07	-0.53 *	-0.01	-0.04	-0.32 ns	-0.01
R^2	0.998	-	-	0.999	-	-	0.999	-	-
Durbin-Watson	1.48	-	-	1.34	-	-	1.42	-	-
RTS	1.06	-	-	1.07	-	-	1.06	-	-

Note: * significance at 1% level; ** significant at 5% level; and ns not significant.

3.3 Economic analysis results

The grain yields of wheat were 5,457, 5,508 and 5,833 kg ha^{-1} in the years 2008, 2009 and 2010 respectively. The total cost and the gross value of production were calculated. The total costs were 879, 952 and 1,011 \$ ha^{-1} in the years 2008, 2009 and 2010 respectively, while the gross production values were found to be 1,690, 1,836 and 1,919 \$ ha^{-1} for the same years. The variable costs were 67%, 65% and 67% of total costs in the years 2008, 2009 and 2010 respectively. Also, the benefit-cost ratios were calculated to be 1.94, 1.92, and 1.89 for the same years. Other researchers reported similar results, such as: 0.86 for cotton (Yilmaz et al., 2005) and 2.09 for canola (Unakitan et al., 2010).

3.4 Sensitivity analysis results

The MPP was technique used for studying sensitivity of energy inputs on production based on response coefficient of inputs. The results are shown in Table 5 for Model I. The major MPPs were water for irrigation, human labor and water for irrigation as 1.39, 1.36 and 1.54 in the years 2008, 2009 and 2010, respectively. This indicates that additional use of 1 MJ for each of the water for irrigation, human labor, and water for irrigation energy would result in an increase in yield by 1.39, 1.36 and 1.54 kg in the years 2008, 2009, and 2010 respectively. So these inputs have a strong impact on the yield with large sensitivity coefficients. In the study area, labors are mainly employed for irrigation operation. Mobtaker et al. (2010) reported that the major MPP was due to human labor energy (7.37), followed by machinery energy (1.66) in barley production.

The values of MPP for Models II and III are shown Table 6 and 7 respectively. In Model II the major MPP was for RE as 1.14, 1.16 and 1.15 in the years 2008, 2009 and 2010 respectively. This indicates that an additional use of 1 MJ of RE energy form would lead to an additional increase in yield by 1.14, 1.16, and 1.15 kg respectively.

The RTS values for Models I to III Equation (8), Equation (9) and Equation (10) were calculated by gathering the regression coefficients and shown in Tables 5 to 7. The RTS value of Model I, for wheat yield were 1.06, 1.07 and 1.06 in the years 2008, 2009 and 2010, respectively. Thus, there prevailed an IRS for estimated model. This revealed that a 1% increase in the total energy inputs utilization would lead in 1.06, 1.07 and 1.06 % increase in the wheat yield for this model in the years 2008, 2009 and 2010 respectively. It was calculated more than unity in the study done by Mobtaker et al. (2010) and Manes and Singh (2005). In all three years, the RTS values in Model II were DRS (Table 6), but in Model III they were IRS (Table 7).

4 Conclusion

The amount of inputs and output used in wheat production in Abyek town of Ghazvin province, Iran was investigated for years from 2008 to 2010. Total equivalent energy of inputs and outputs were calculated and the following results were found:

1) The energy ratios were obtained as 2.03, 2.08 and 2.11 for years 2008, 2009 and 2010, respectively. It was shown good energy use efficiency.

2) The amounts of direct, indirect, renewable and non-renewable energies were calculated and it was found that contribution percentage of direct energy was more that indirect energy on wheat production in Abyek.

Also, contribution percentage of non-renewable energy was more that renewable energy in yield of wheat.

3) Cobb–Douglas production function was used to estimate the energy inputs and wheat yield relationship. It was found that machinery, electricity, and fertilizer had always negative effects on wheat yield, while diesel fuel, water for irrigation, and seeds had always positive impact.

4) The major MPPs were water for irrigation for the years 2008, 2010 and human labor for the year of 2008 respectively. In Model II, The major MPP belonged for renewable energy.

5) To increase energy ratio and energy productivity, the fertilizer, fuel uses and losses should be reduced in this region.

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