Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 52 (2012) 11500-11505

ISSN: 2229-712X

# Energy input–output modeling and economical analyze for corn grain production in Iran

Morteza Taki[a,*], Hassan Ghasemi Mobtaker[b] and Nasim Monjezi[c]

[a]Young Researches Club Shahreza Branch, Islamic Azad University, Shahreza, Iran.

[b]Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran.

[c]Department of Agricultural Machinery, Faculty of Agriculture, Chamran University, Iran.

**ARTICLE INFO**

**Article history:**

Received: 26 September 2012;
Received in revised form:
11 November 2012;
Accepted: 15 November 2012;

**Keywords**

Corn grain,
Cobb–Douglas function,
Greenhouse gas,
Iran.

**ABSTRACT**

The energy use and influences of energy inputs on output levels in corn grain production were investigated. For this purpose, the data on 100 corn grain production farms in the Khozestan province, Iran, were collected and analyzed. The output level was specified as a function inputs and output, and ordinary least squares were employed to estimate equation parameters. The results indicated that total energy input for corn grain production was about 392323 $MJha^{-1}$; Chemical fertilizers (with 44 %) and electricity (with 27 %) were amongst the highest energy inputs for corn grain production. The energy ratio, energy productivity, specific energy and net energy were 2.6, 0.18 $kgMJ^{-1}$, 5.66 $MJkg^{-1}$ and 59248.58 $MJha^{-1}$ respectively. The regression results indicated that the contribution of energy inputs on crop yield was significant. Sensitivity analysis indicates that the major MPP was drawn for seed and chemical fertilizers energy. Economic analysis indicated that the total cost of production for one hectare of corn grain production was around 1955 $. Accordingly, the benefit–cost ratio was 1.75. The total amounts of $CO_2$ for corn grain production was calculated as 1.54 $tonha^{-1}$, which indicated the high $CO_2$ output in this cultivation. The use of diesel fuel and chemical fertilizer is in excess for corn grain production, causing an environmental risk problem in the region. The high rate of non-renewable energy utilization in this region can be controlled by using farmyard and green manure instead of chemical fertilizers.



## Introduction

Energy is one of the most important material bases for the economic growth and social development of a country or region. Scientific forecasts and analysis of energy consumption will be of great importance for the planning of energy strategies and policies (Lianga *et al.*, 2007). Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Efficient use of energy in agriculture is one of the principal requirements for sustainable agricultural production. Improving energy use efficiency is becoming increasingly important for combating rising energy costs, depletion of natural resources and environmental deterioration (Dovì *et al.*, 2009).The development of energy efficient agricultural systems with low input energy compared to the output of food can reduces the greenhouse gas emissions from agricultural production systems (Dalgaard *et al.*, 2001). The energy input–output analysis is usually made to determine the energy efficiency and environmental aspects. This analysis will determine how efficient the energy is used. Sensitivity analysis quantifies the sensitivity of a model's state variables to the parameters defining the model. It refers to changes in the response of each of the state variables which result from small changes in the parameter values. Sensitivity analysis is valuable because it identifies those parameters which have most influence on the response of the model. It is also an essential prerequisite to any parameter optimization exercise (Cbalabi and Bailey, 1991).

In recent years, many researchers have been investigated the energy use for agricultural crop production (Liu *et al*, 2010). Franzluebbers and Francis (1995) investigated the energy requirements for maize and sorghum management systems in Nebraska, USA. They concluded that energy ratio decreased with N fertilizer application in all management systems, except with cereal as previous crop and low initially available N.

Canakci *et al.* (2005) studied the energy use patterns of wheat, cotton, maize and sesame in Turkey and found that the fertilizer application have the highest energy source in total inputs with the share of 52.7% in maize production. Nguyen *et al.* (2007) studied energy balance of cassava and found the positive energy balance for the production of ethanol from cassava. They illustrated greenhouse gas (GHG) emissions of cassava in Thailand are low (about 0.96 kg per liter of cassava-based ethanol used versus 2.6 kg $CO_2$). Hokazono and Hayashi (2011) in the study on environmental impacts during conversion from conventional to organic farming, used the time-series data obtained from a five-year on-farm trial were applied to an LCA of three rice production systems in Japan. Four impact categories, global warming, acidification, eutrophication, and non-renewable energy, were used for the assessment. Results showed that the environmental impacts of organic rice production were higher than those of the other two modes of rice production in four categories covered in the study on average. They reported that the cause of higher variability in the impacts of organic farming at the initial phase was associated mainly with the instability of the organic rice yield. A further

**Tele:**
**E-mail addresses: mtaki88@ms.tabrizu.ac.ir**

comparative review of studies on agricultural products can be found in (Mobtaker *et al.*, 2010; Houshyar *et al.*, 2010; Mousavi–Avval *et al.*, 2011a; Mousavi–Avval *et al.*, 2011b; Börjesson, and Tufvesson, 2011, Taki *et al.*, 2012a; Taki *et al.*, 2012b).

On this basis, the main objective of this study was to examine energy use pattern and specification of GHG emission for corn grain production in Khozestan province of Iran. Furthermore, this study was aimed to explore the relationship between output and energy inputs using various functional forms. In addition, the relationship is also examined for different energy sources in the form of renewable and non-renewable, direct and indirect energy. Once estimated, the models yield elasticity of energy inputs and energy sources for Iranian agriculture as well as a set of results that can be used by policy makers or other relevant agents in order to ensure sustainability and more efficient energy use.

## Material and methods

Khozestan province is in Longitude of 48 degree and 40 minutes E and Latitude of 31 degree and 20 minutes N from equator. It is located in the height of 18 meter above the sea level. It`s area is 20477 hectare, which is included rural districts of Bavi, Elhai, Hamidie, Gabir, Susie, Sofhe, Gambue, and Ghizanie. Fertile lands of this province, which have used for cultivating corn grain production, were 88230 hectare in the cultivation period of 2009–2010 (Anonymous, 2009).

Data on corn grain production were collected from 100 farms in Khozestan province (Ahvaz city) using a face to face questionnaire. The collected data belonged to 2010–2011 production period. The size of sample was determined using the simple random sampling method. This method is expressed as below (Kizilaslan, 2009):

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

where *n* is the required sample size, *s*, the standard deviation, *t*, the t value at 95% confidence limit (1.96), *N*, the number of holdings in target population and *d*, the acceptable error (permissible error was chosen as 5%).

The inputs used in the production of corn grain were specified in order to calculate the energy equivalences in the study. Inputs in corn grain production were: human labour, machinery, diesel fuel, chemical fertilizers, biocides, seed and electricity for irrigation. The output was corn grain. The energy equivalents given in Table 1 were used to calculate the input amounts.

**Table 1. Energy equivalent of inputs and output in agricultural production**

| Inputs (unit) | Unit | Energy equivalent (MJ unit$^{-1}$) | Reference |
|---|---|---|---|
| *A. Inputs* | | | |
| 1. Human labour | h | 1.96 | (Mohamadi *et al*, 2008) |
| 2. Machinery | h | 64.80 | (Kizilaslan, 2009) |
| 3. Diesel fuel | l | 56.31 | (Kizilaslan, 2009) |
| 4. fertilizers | | | |
| (a) Nitrogen | kg | 66.14 | (Yilmaz *et al*, 2005) |
| (b) Phosphate ($P_2O_5$) | kg | 12.44 | ((Yilmaz *et al*, 2005) |
| (c) Potassium ($K_2O$) | kg | 11.15 | (Yilmaz *et al*, 2005) |
| 5. Biocide | kg | 120 | (Mohamadi and Omid 2010) |
| 6. Electricity | kWh | 11.93[a] | (Ozkan *et al*, 2004) |
| 7. Seed (hybrid) | kg | 100 | (Kitani, 1999) |
| *B. Output* | | | |
| 1. corn | kg | 14.7 | (Singh and Mittal, 1992) |

[a] This coefficient used according to the efficiency of power plants and power loss of distribution networks reported in references for Iran. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity, specific energy and net energy gain were calculated (Mohammadi and Omid, 2010):

$$\text{Energy use efficiency}=\frac{\text{Energy output}(\text{MJ ha}^{-1})}{\text{Energy input}(\text{MJ ha}^{-1})} \quad (2)$$

$$\text{Energy productivity}=\frac{\text{Maize output}(\text{kg ha}^{-1})}{\text{Energy input}(\text{MJ ha}^{-1})} \quad (3)$$

$$\text{Specific energy}=\frac{\text{Energy input}(\text{MJ ha}^{-1})}{\text{Corn output}(\text{kg ha}^{-1})} \quad (4)$$

$$\text{Net energy} = \text{Energy Output (MJ ha}^{-1}) - \text{Energy Input (MJ ha}^{-1}) \quad (5)$$

The energy use efficiency is one of the indices that show the energy efficiency of agriculture. In particular, this ratio, which is calculated by the ratio of input fossil fuel energy and output food energy, has been used to express the ineffectiveness of crop production in developed countries (Unakitan *et al.*, 2010). An increase in the ratio indicates improvement in energy efficiency, and vice versa. Changes in efficiency can be both short and long term, and will often reflect changes in technology, government policies, weather patterns, or farm management practices. By carefully evaluating the ratios, it is possible to determine trends in the energy efficiency of agricultural production, and to explain these trends by attributing each change to various occurrences within the industry (Unakitan *et al.*, 2010).

The greenhouse gas (GHG) emissions were beyond the scope of this analysis and the corresponding amount was calculated. The diesel fuel combustion can be expressed as fossil $CO_2$ emissions with equivalent of 2764.2 g $L^{-1}$. Also, the machinery and fertilizer supply terms can be expressed in terms of the fossil energy required to manufacture and transport them to the farm with $CO_2$ equivalents of 0.071 Tg $PJ^{-1}$ and 0.058 Tg $PJ^{-1}$ for machinery and chemical fertilizers, respectively (Pishgar Komleh *et al.*, 2011).

In this study also the economic analysis of corn grain production was investigated. For this purpose the net return, gross profit and benefit to cost ratio were calculated. The net return was calculated by subtracting the total cost of production from the gross value of production per hectare. The gross return was calculated by subtracting the variable cost of production. The benefit–cost ratio was calculated by dividing the gross value of production by the total cost of production per hectare:

In order to estimate the economic model, a mathematical function needs to be specified. For this purpose, several functions were tried, and the Cobb–Douglas production function was chosen since it produced better results among the others. The Cobb–Douglas production function is expressed in general form as follows (Hatirli *et al.*, 2005):

$$Y = f(x)\exp(u) \quad (11)$$

This function has been used by several authors to examine the relation between energy inputs and yield (Hatrili *et al.*, 2006). Equation (11) can be linearized and re–written as:

$$\ln Y_i = a+\sum_{j=1}^{n}\alpha_j \ln(X_{ij})+e_i \quad i=1, 2, 3\ldots n \quad (12)$$

Assuming that when the energy input is zero, the crop production is zero too, Eq. (12) was reformed to (Hatirli *et al.*, 2006):

$$\ln Y_i = \sum_{j=1}^{n}\alpha_j \ln(X_{ij})+e_i \quad (13)$$

Eq. (13) can be expressed in the following form:

$$\ln Y_i=\alpha_1\ln X_1+\alpha_2\ln X_2+\alpha_3\ln X_3+\alpha_4\ln X_4+\alpha_5\ln X_5+\alpha_6\ln X_6+\alpha_7\ln X_7+e_i \quad (14)$$

Using Eq. (14), the effect of energy inputs on corn grain yield for each input was studied. On the other hand, corn grain (endogenous variable) was assumed to be a function of human labour, machinery, diesel fuel, chemical fertilizers, biocides, electricity and seed energy (exogenous variables).

The study was also aimed at investigating the relationship between output and different energy forms. More specifically, we considered different energy forms as renewable or nonrenewable, as direct or indirect. As a functional form, the Cobb–Douglas production function was selected and specified in the following forms (Hatirli *et al.*, 2005):

$$\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i \quad (15)$$

$$\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \quad (16)$$

Eqs. (14)–(16) were estimated using ordinary least square technique.

In the last part of the study sensitivity analysis of energy inputs on corn grain yield was carried out based on the response coefficients of inputs by use of marginal physical productivity (MPP) technique. The MPP of a factor indicates the change in output with a unit change in the factor input in question, keeping all other factors constant at their geometric mean level. To calculate MPP, Eq. (17) was used (Nguyen *et al.*, 2007):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_j)} \times \alpha_j \quad (17)$$

Where $MPP_{xj}$ is marginal physical productivity of *j*th input, $\alpha_j$ regression coefficient of *j*th input, *GM(Y)* geometric mean of corn grain yield and *GM* $(X_{ij})$ geometric mean of *j*th input energy on per hectare.

In production, returns to scale refer to changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). In the Cobb–Douglas production function, it is indicated by the sum of the elasticities derived in the form of regression coefficients. If the sum of the coefficients is greater than unity ($\sum_{i=1}^{n}\alpha_i > 1$), then it could be concluded that the increasing returns to scale, on the other hand if the latter parameter is less than unity ($\sum_{i=1}^{n}\alpha_i < 1$), then it is indicated that the decreasing returns to scale; and, if the result is unity ($\sum_{i=1}^{n}\alpha_i = 1$), it shows that the constant returns to scale.

Basic information on energy inputs and corn yields were entered into Excel's spreadsheet and simulated using SPSS 15 software.

## Results and discussion

### *Analysis of input–output energy use and GHG emission in corn grain production*

The inputs used in corn grain production and their energy equivalents with output energy rates are shown in the Table 2. Also the percentage distribution of the energy associated with the inputs showed in Fig. 1. The results revealed that 45.98 h of human labour and 18.85 h of machinery power per hectare were required to produce corn grain in the research area. The amount of total fertilizers and biocides used for corn grain growing were 403.24 and 4.54 kg ha$^{-1}$, respectively. The total energy input for various processes in the corn grain production was calculated to be 39232.79 MJha$^{-1}$. Pishgar Komleh *et al.*, (2011) concluded that the input energy for corn silage production was to be 68928 MJha$^{-1}$. The average inputs energy consumption was highest for total fertilizers. Similar results have been reported in the literature that the energy input of chemical fertilizers has the biggest share of the total energy input in agricultural crops production (Tsatsarelis, 1993; 2007; Kizilaslan, 2009). Consequently, Börjesson and Tufvesson (2011) reported that fertilizers and diesel fuel were the main energy consuming inputs in wheat, sugar beet, canola, ley crops, maize and willow productions.

**Table 2. Amounts of inputs, outputs and energy inputs and output in corn grain production**

| Inputs (unit) | Quantity per unit area (ha) | Total energy equivalent (MJ ha$^{-1}$) |
|---|---|---|
| *A. Inputs* | | |
| 1. Human labour (h) | 45.98 | 90.12 |
| 2. Machinery (h) | 18.85 | 1221.69 |
| 3. Diesel fuel (L) | 131.72 | 7417.30 |
| 4. Chemical fertilizers (kg) | 403.24 | 17030.91 |
| 5. Biocide (kg) | 4.54 | 544.54 |
| 6. Electricity (kWh) | 875.12 | 10440.23 |
| 7. Seed (kg) | 24.88 | 2488.00 |
| The total energy input (MJ) | | 39232.79 |
| *B. Output* | 6555.04 | |
| 1.grain corn (kg) | 12250.00 | 96359.10 |
| Total energy output (MJ) | | 96359.10 |

The inputs energy consumption was least for human labour (90.12 MJha$^{-1}$). The share of this input was less than one. Similar results have been reported by researchers (Kizilaslan, 2009; Mobtaker *et al*, 2010). The average yield of corn grain were obtained to be 12250 kg ha$^{-1}$, accordingly, the total energy output per hectare were calculated as 96359.10 MJha$^{-1}$. Fertilization usage management and integrating a legume into the crop rotation are energetically favorable to reduce the need for chemical fertilizer. In this region, usage of composts, chopped residues or other soil amendments may increase soil organic matter content and fertility in the medium term and so reduce the chemical fertilizer energy requirements. Also, applying a better machinery management technique, proper tractor selection to reduce diesel fuel requirement or technological upgrade to substitute fossil fuels with renewable energy sources help to minimize the fossil fuel usage and thus to reduce the environmental footprints (Mousavi–Avval *et al.*, 2011b).

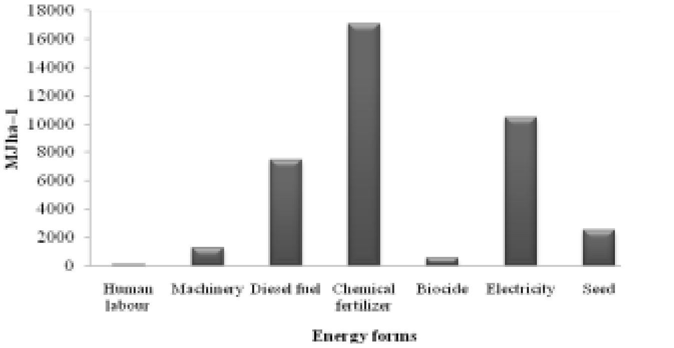


**Fig.1. The anthropogenic energy input ratios in the production of corn grain**

The energy use efficiency, energy productivity, specific energy and net energy gain of corn grain production in the Khozestan province are listed in Table 3. The energy use efficiency in this production was found to be 2.60. The energy ratio is often used as an index to examine the energy efficiency in crop production (Kuesters and Lammel, 1999).

The energy ratio for some crops are reported as 2.8 for wheat, 4.8 for cotton, 3.8 for maize and 1.5 for sesame (Canakci *et al.*, 2005), and 1.25 for potato (Mohammadi *et al.*, 2008). The energy productivity and specific energy of corn grain production was calculated as 0.18 kg $MJ^{-1}$and 5.66 MJ $kg^{-1}$ respectively. The net energy of corn grain production was found to be 59248.58MJ $ha^{-1}$. It indicates that in this crop production energy is gained (net energy is greater than zero). In literature, similar results have been reported (Mandal *et al.*, 2002; Esengun *et al.*, 2007). Pishgar Komleh *et al.* (2011) studied energy efficiency, energy productivity, specific energy and net energy for corn silage which amount of above indices were reported as 2.27, 0.28 $kgMJ^{-1}$, 3.76 MJ $kg^{-1}$ and 79452 MJ $ha^{-1}$, respectively.

**Table 3. Energy input–output ratio in corn grain production**

| Items | Unit | Quantity |
|---|---|---|
| Energy use efficiency | – | 2.60 |
| Energy productivity | kg $MJ^{-1}$ | 0.18 |
| Specific energy | MJ $kg^{-1}$ | 5.66 |
| Net energy gain | MJ $ha^{-1}$ | 59248.58 |

The distribution of inputs used in the production of corn grain according to the direct, indirect, renewable and non–renewable energy groups, are given in Table 4. It is seen that the direct and indirect energy resources are nearly equally utilized (45.74% and 54.26%), but it is also seen that the ratios of renewable and non–renewable energy are fairly different from each other (33.18% and 66.82%). It can be seen that the ratio of renewable and non-renewable energy are fairly different from each other in this cultivation. The ratio of renewable energy including the human labour, seeds and electricity, within the total energy is very low. Renewable energy resources (solar, hydroelectric, biomass, wind, ocean and geothermal energy) are inexhaustible and offer many environmental benefits over conventional energy sources. Each type of renewable energy also has its own special advantages that make it uniquely suited to certain applications (Miguez *et al.*, 2010).

The use of renewable energy offers a range of exceptional benefits, including: a decrease in external energy dependence; a boost to local and regional component manufacturing industries; promotion of regional engineering and consultancy services specializing in the use of renewable energy, decrease in impact of electricity production and transformation; increase in the level of services for the rural population; creation of employment, etc. (Kaya, 2006).

Within the enterprise that was analyzed, 66.82 % of input energy resources used for the production of corn grain was non–renewable energy.

**Table 4. Energy forms in corn grain production**

| Items | Unit | Quantity |
|---|---|---|
| Direct energy [a] | MJ $ha^{-1}$ | 17947.65 (45.74%) |
| Indirect energy [b] | MJ $ha^{-1}$ | 21285.14 (54.26%) |
| Renewable energy [c] | MJ $ha^{-1}$ | 13018.35 (33.18%) |
| Non–renewable energy [d] | MJ $ha^{-1}$ | 26214.44 (66.82%) |
| Total energy input | MJ $ha^{-1}$ | 39232.79 |

[a] include human labour, diesel fuel and electricity power
[b] include the chemicals fertilizers, biocide, seeds and machinery
[c] include human labour, seeds and electricity
[d] include diesel fuel, chemicals fertilizers, biocide and machinery

Results indicated that corn grain production is mostly depending on fossil energy sources. As it can be seen in Table 5, the total amount of $CO_2$ was calculated as 1.54 tones. Manufacturing chemical fertilizers had the highest share followed by diesel fuel and manufacturing machinery. Cellura *et al*. (2011) investigated the Life Cycle Assessment (LCA), energy and environmental performances of peppers, melons, tomatoes, cherry tomatoes, and zucchini in different typologies of greenhouses (tunnel and pavilion) in Italian. They reported that for all the examined vegetables the packaging step and the greenhouse structures have a relevant share in the environmental impact distribution.

**Table 5. Greenhouse emission in corn grain production**

| Input | consumption (MJ) | Equivalent (Tg ($CO_2$) $PJ^{-1}$) | Amount of $CO_2$ ($tonha^{-1}$) | Percentage |
|---|---|---|---|---|
| Diesel fuel | 7417.30 | 0.0578 | 0.43 | 27.92 |
| Machinery | 1221.69 | 0.071 | 0.09 | 5.84 |
| fertilizers | 17575.45 | 0.058 | 1.02 | 66.24 |
| Total | 26214.44 | – | 1.54 | 100 |

**Econometric model estimation and sensitivity analyze of corn grain production**

One of the main objectives of this study was to explore the relationship between total output and energy inputs in some detail. For this purpose, Cobb–Douglas production function was specified and estimated using ordinary least square estimation technique. One of the features of this production function is that estimated coefficients represent elasticities. Furthermore, Cobb–Douglas production function imposes a priori restrictions on patterns of substitution among inputs. In particular, elasticities of substitution among all inputs must be equal to unity. From the view point of output–input ratios, higher input use, ceteris paribus, is bound to mean lower partial productivity or efficiency, if estimated coefficient is less than one. Eqs. (14)–(16) were estimated using ordinary least squares estimation and the results are provided in Table 6.

**Table 6. Econometric estimation results of inputs**

| Endogenous variable: yield | Coefficient | *t*–ratio | MPP |
|---|---|---|---|
| Exogenous variables | | | |
| Eq.14: $\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + e_i$ | | | |
| Human labour | 0.005 | .0127 | 5.496 |
| Machinery | 0.064 | 2.450** | 5.339 |
| Diesel fuel | 0.112 | 4.147* | 1.502 |
| Chemical fertilizers | 0.179 | 3.067* | 2.400 |
| Biocides | 0.041 | 2.405** | 9.857 |
| Electricity | 0.087 | 4.303* | 0.876 |
| Seed | 0.222 | 10.773* | 32.770 |
| Durbin–Watson | 2.038 | | |
| $R^2$ | 0.98 | | |
| Return to scale | 1.718 | | |
| Eq. 15: $\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i$ | | | |
| Direct energy | 0.419 | 10.638* | 2.300 |
| Indirect energy | 0.749 | 19.143* | 3.788 |
| Durbin–Watson | 1.968 | | |
| $R^2$ | 0.99 | | |
| Return to scale | 1.168 | | |
| Eq. 16: $\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$ | | | |
| Renewable energy | 0.197 | 8.529* | 1.882 |
| Non–renewable energy | 0.950 | 45.336* | 3.506 |
| Durbin–Watson | 2.044 | | |
| $R^2$ | 0.97 | | |
| Return to scale | 1.147 | | |

*, ** Indicates significance at 1% and 5% levels, respectively.

Since time series data were used in this study, autocorrelation might be a potential concern, and therefore needed to be tested, using the Durbin–Watson test. Computed Durbin–Watson values were calculated as 2.03, 1.96 and 2.04 for Eqs. (14)–(16), showing that there was no autocorrelation at the 5% significance level in the estimated models. The $R^2$ values were calculated as 0.98, 0.99 and 0.97 for these equations, indicating that around 98% of the variability in the total annual grain equivalent was explained by these models.

As can be seen from Table 6, all exogenous variables had a positive impact and were found statistically significant on corn grain yield (expected biocides and seed energy). Table 6 showed that, Seed had the highest impact (0.22) among other inputs and significantly contributed on the productivity at 1% level. It indicates that a 1% increase in the energy machinery input led to 0.22% increase in yield in these circumstances. The second important input was found as chemical fertilizers with 0.17 elasticity followed by diesel fuel with 0.11 elasticity.

The sensitivity of energy inputs was analyzed by using MPP value. The results showed that seed energy had the highest value (32.7) followed by biocides, human labour and machinery with MPP values of 9.8, 5.4 and 5.3, respectively. These results shown in Table 6 indicate that additional use of 1 MJ for each of seed, biocides and human labour inputs would result in an increase of 32.7, 9.8 and 5.4 MJ in corn grain production yield, respectively

Pishgar Komleh *et al.* (2011) were examined the sensitivity of energy inputs on corn silage productivity in Iran. They reported that MPP of seed, fertilizer and fuel, were calculated to be 0.87, 0.62 and 0.31, respectively.

Regression results for Eqs 16 and 17 are given in Table 6. The results revealed that, the impact of all forms of energy inputs as direct, indirect, renewable and non–renewable were significant at 1% level. Indirect and non–renewable had more impact on output yield. The MPP values of direct, indirect, renewable and non-renewable were 2.3, 3.7, 1.8 and 3.5, respectively.

**Economic analysis of corn grain production**

The total cost of corn grain production and the gross value of this production was calculated and shown in Table 7. The fixed and variable expenditures included in the cost of production were calculated separately. The total expenditure for the corn grain production was 1955 $\$ha^{-1}$ while the gross production value was found to be 3430 $\$ha^{-1}$ according to the results of the research. The share of variable costs in total costs of corn grain production was 42%. With respect to results of Table 7, the benefit–cost ratio from corn grain production in the surveyed farms was calculated to be 1.75. Other researchers reported similar results, such as 2.37 for orange (Ozkan *et al.*, 2004), 2.53 for sweet cherry (Demirjan *et al.*, 2006) and 1.57 for corn silage (Pishgar *et al.*, 2011).

**Table 7. Economic analysis of corn grain production**

| Cost and return components | Unit | Value |
|---|---|---|
| Yield | $kgha^{-1}$ | 12250 |
| Sale price | $\$kg^{-1}$ | 0.280 |
| Gross value of production | $\$ha^{-1}$ | 3430 |
| Variable cost of production | $\$ha^{-1}$ | 831 |
| Fixed cost of production | $\$ha^{-1}$ | 1124 |
| Total cost of production | $\$ha^{-1}$ | 1955 |
| Total cost of production | $\$kg^{-1}$ | 0.159 |
| Gross return | $\$ha^{-1}$ | 2599 |
| Net return | $\$ha^{-1}$ | 1475 |
| Benefit to cost ratio | – | 1.754 |
| Productivity | $kg\$^{-1}$ | 6.265 |

**Conclusion**

In this study, relationship between energy inputs and yield and sensitivity analysis of energy inputs for corn grain production were investigated in Khozestan province of Iran. Results showed that corn grain production consumed a total energy of 39232.79 $MJha^{-1}$, which was mainly due to chemical fertilizers (44% of total energy). The elasticity estimates of seed energy was found as 0.22, had major impact in corn grain production, followed by chemicals fertilizers (0.17) and diesel fuel (0.11). Energy use efficiency, energy productivity, specific energy and net energy of corn grain production were 2.6, 0.18 $kgMJ^{-1}$, 5.66 $MJkg^{-1}$ and 59248.58 $MJha^{-1}$, respectively. The MPP of direct, indirect and renewable and non–renewable energies on yield were estimated as 2.3, 3.7, 1.8 and 3.5, respectively. The benefit–cost ratio was found to be 1.75 in the result of economical analysis of corn grain production. The mean net return from corn grain production was obtained 1475 $\$ha^{-1}$.

**References**

Anonymous. (2009). Annual agricultural statistics. Ministry of Jihad–e–Agriculture of Iran. http://www.maj.ir (in Persian).

Börjesson, P. and Tufvesson. L.M. (2011). Agricultural crop–based biofuels – resource efficiency and environmental performance including direct land use changes. Journal of Cleaner Production 19: 108–120.

Canakci, M., Topakci. M., Akinci. I. and Ozmerzi. A. (2005). Energy use pattern of some field crops and vegetable production: case study for Antalya region, Turkey. Energy Convers. Manage 46: 655–666.

Cbalabi, ZS. and Bailey. BJ. (1991). Sensitivity analysis of a non-steady state model of the greenhouse microclimate. Agric. For. Meteorol 56: 111–127.

Cellura, M., Longo. S. and Mistretta. M. (2011). Life Cycle Assessment (LCA) of protected crops: an Italian case study. Journal of Cleaner Production. http://dx.doi.org/10.1016/j.jclepro.2011.10.021.

Dalgaard, T., Halberg. N. and Porter. JR. (2001). A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. Agric. Ecosyst. Environ 87: 51–65.

Demirjan, V., Ekinci. KK., Akbolat. DHM. and Ekinci. C. (2006). Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. Energy Convers. Manage 47: 1761–1769.

Dovì, V.G., Friedler. F., Huisingh. D. and Klemes. J.J. (2009). Cleaner energy for sustainable future. Journal of Cleaner Production 17: 889–895.

Esengun, K., Gunduz. O. and Erdal. G. (2007). Input–output energy analysis in dry apricot production of Turkey. Energy Convers. Manage 48: 592–598.

Franzluebbers, AJ. and Francis. CA. (1995). Energy output: input ratio of maize and sorghum management systems in eastern Nebraska. Agric. Ecosyst. Environ 53: 271–278.

Hatirli, S.A., Ozkan. B. and Fert. C. (2005). An econometric analysis of energy input–output in Turkish agriculture. Renew. Sust. Energy Rev 9: 608–623.

Hatirli, S.A., Ozkan. B. and Fert. C. (2006). Energy inputs and crop yield relationship in greenhouse tomato production. Renew. Energy 31: 427–438.

Hokazono, S. and Hayashi. K. (2011). Variability in environmental impacts during conversion from conventional to organic farming: a comparison among three rice production systems in Japan. Journal of Cleaner Production. http://dx.doi.org/10.1016/j.jclepro.2011.12.005.

Kaya, D. (2006). Renewable energy policies in Turkey. Renew. Sustain. Energy Rev 10: 152–163.

Kitani, O. (1999). CIGR Handbook of Agricultural Engineering. Vol. 5., Energy and Biomass Engineering. ASAE publication, St Joseph, MI.

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

Kuesters. J. and Lammel. J. (1999). Investigations of the energy efficiency of the production of winter wheat and sugar beet in Europe. Eur. J. Agron 11; 35–43.

Lianga, QM., Fana. Y. and Wei. YM. (2007). Multi-regional input–output model for regional energy requirements and $CO_2$ emissions in China. Energy Policy 35: 1685–1700.

Liu, Y., Langer. V., Høgh-Jensen. H. and Egelyng. H. (2010). Life cycle assessment of fossil energy use and greenhouse gas emissions in Chinese pear production. Journal of Cleaner Production 18: 1423-1430.

Mobtaker, HG., Keyhani. A., Mohammadi. A., Rafiee. SH. and Akram. A. (2010). Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agric. Ecosyst. Environ 137: 367–372.

Mandal, K.G., Saha. K.P., Gosh. P.L., Hati. K.M. and Bandyopadhyay. K.K. (2002). Bioenergy and economic analyses of soybean–based crop production systems in central India. Biomass. Bioenergy 23: 337–345.

Miguez, JL., Lopez-Gonzalez. LM., Sala. JM., Porteiro. J., Granada. E. and Moran. JC. (2006). Review of compliance with EU–2010 targets on renewable energy in Galicia (Spain). Renew. Sustain. Energy Rev 10: 225–247.

Mohammadi, A., Omid. M. (2010). Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Appl Energy 87: 191–196.

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

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

Mousavi–Avval, SH., Rafiee. S., Jafari. A. and Mohammadi. A. (2011b). Energy flow modeling and sensitivity analysis of inputs for canola production in Iran. Journal of Cleaner Production 35: 1464–1470.

Nguyen, TLT., Gheewala. SH. and Garivait. S. (2007). Energy balance and GHG–abatement cost of cassava utilization for fuel ethanol in Thailand. Energy Policy 35: 4585–4596.

Ozkan, B., Akcaoz. H. and Fert. C. (2004). Energy input–output analysis in Turkish agriculture. Renew. Energy 29: 39–51.

Pishgar Komleh, SH., Keyhani. A., Rafiee. SH. and Sefeedpary. P. (2011). Energy use and economic analysis of corn silage production under three cultivated area levels in Tehran province of Iran Energy 36: 3335–3341.

Singh, S. and Mittal. J.P. (1992). Energy in Production Agriculture. Mittal Pub. New Dehli.

Taki, M., Ajabshirchi, Y. and Mahmoudi, A. (2012a).Application of parametric and non-parametric method to analyzing of energy consumption for cucumber production in Iran.Modern Applied Science. 6(1): 75-87.

Taki, M., Ajabshirchi, Y and Mahmoudi, A. (2012b). Prediction of output energy for wheat production using artificial neural networks in Esfahan province of Iran. Journal of Agricultural Technology 8(4): 1229-1242.

Tsatsarelis, C.A. (1993). Energy inputs and outputs for soft winter wheat production in Greece. Agric. Ecosyst. Environ 43: 109–118.

Unakitan, G., Hurma. H. and Yilmaz. F. (2010). An analysis of energy use efficiency of canola production in Turkey Energy 35: 3623–3627.

Yilmaz, I., Akcaoz. H. and Ozkan. B. (2005). An analysis of energy use and input costs for cotton production in Turkey. Renew Energy 30: 145–55.