INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES

IJPAES

VOLUME-2, ISSUE-3, JULY-SEPT-2012 ISSN 2231-4490

Copy Rights @ 2012

Coden : IJPAES www.ijpaes.com

*Received: 24th May-2012* *Revised: 27th May-2012* *Accepted: 30th May-2012*

***Research article***

# SENSITIVITY ANALYSIS OF ENERGY INPUTS FOR MAIZE PRODUCTION SYSTEM IN KERMANSHAH PROVINCE OF IRAN

Reza Abdi[1], Amir Hematian[2], Hassan Ghasemi Mobtaker*[3] and Ebrahim Zarei Shahamat[4]

[1]Assistant professor, Department of Agricultural Machinery Engineering, University of Tabriz,
.Tabriz, Iran
.Young Researchers Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran [2]
[3] Postgraduate student, Department of Agricultural Machinery Engineering,
University of Tehran, Karaj, Iran
[4]Postgraduate student, Department of Mechanization and Agricultural Machinery Engineering, Ramin Agricultural and Natural Resources University, Ahvaz, Iran.
*Tel: (+98) 2612801011 Fax: (+98) 2612808138 E-mail: mr.mobtaker@yahoo.com*

**ABSTRACT:** The aims of this study were to investigate influences of energy inputs and energy forms on output levels and evaluation of inputs sensitivity for maize production in Kermanshah province, Iran. The sensitivity of energy inputs was estimated using the marginal physical productivity (MPP) method and partial regression coefficients on maize yield. Data were collected from 72 maize farms in August and September 2011. The sample volume was determined by random sampling method. The total energy input was 26.91 GJ ha$^{-1}$. The chemical fertilizer (N and P) with 56 percent had the biggest share of total energy inputs. Econometric model evaluation showed that the human labor energy was the most significant input affecting the output level. Sensitivity analysis results indicate that with an additional use of 1 MJ for each of seeds, machinery and water for Irrigation energy would result in an increase in maize yield by 6.02, 5.57 and 5.14 kg, respectively.

**Keywords:** Energy, maize, Modeling, Cobb–Douglas, Sensitivity of energy

## INTRODUCTION

Maize is the most widely grown crop in the Iran with 1,650,000 tons in a cropping area of 225,000 ha [1]. Energy has been a key input of agriculture since the age of sustainable agriculture. It is an established fact worldwide that agricultural production is positively correlated with energy input [2]. Agriculture is both a producer and consumer of energy. 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 [3]. In modern agriculture system input energy is very much more than traditional agriculture system, but energy use efficiently has been redacting in response to no affective use of input energy. Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system [4]. Economic production is a function of many factors such as human labor, capital, natural resources availability of energy and technology. Therefore, both the natural resources are rapidly decreasing and the amount of contaminants is considerably increasing. The best way to lower the environmental hazard of energy use is to increase the energy use efficiency [5]. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. It is also used to compare the different production systems. Energy consumption by the agriculture sectors can be broadly categorized into direct and indirect energy use.

Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings and for lighting on the farm and indirectly in the chemical fertilizers, seed production, machinery and biocides produced off the farm [6,7]. Considerable studies have been conducted on energy use in agriculture [8-11]. While there was few studies on the energy requirements and sensitivity analysis of inputs in maize production. This study was aimed to determine input–output energy use in maize production in Kermanshah, Iran from efficiency of energy consumption point of view. Also, the Cobb–Douglas production function was used to study the sensitivity and the relationship between energy inputs and maize yield.

## MATERIALS AND METHODS

The study was performed in central region of Kermanshah province which is located in the west of Iran; within 34° 41′ latitude and 46° 75′ longitude. Kermanshah region has an 2,324,038 ha farming area, According to Ministry of Jihad-e-Agriculture (MAJ) experts and local officers, there were 19141 ha of this province under irrigated conditions and produced about 215445 tonnes with a share of 7.99% of the Iran total production [1]. A simple random sampling method was used to determine survey volume and the farms were chosen randomly from study region. This method is expressed as below [3, 12].

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

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 holding in target population and d, the acceptable error (permissible error 5%). Consequently calculated sample size in this study was 72. The data were collected using a face to face questionnaire in August and September 2011. The questionnaires included total energy inputs from different sources and yield weight. The inputs used in the production of maize were specified in order to calculate the energy equivalences in the study. Inputs in maize production were: human labor, machinery, diesel fuel, chemical fertilizers, biocides, water for Irrigation and seeds. It should be mentioned that the free sources of energy (solar energy input for photosynthesis) are not accounted for. To calculate the energy equivalent of inputs and output, units in Table 1 were used. In order to obtain a relationship between inputs and yield, a mathematical function needs to be specified. For this purpose different functions were investigated and finally Cobb–Douglas production function was selected; because it produced better results (yielded better estimates in terms of statistical significance and expected signs of parameters). The Cobb–Douglas production function is frequently used in both energy and economics studies to show the relationship between input factors and the level of production [12, 13, 14, 15]. This function is nothing but the Logarithmic functions are used where changes of variables in the model show as many folds compared to one another. The coefficient of variables in this function which is in log form also represents elasticities [15]. Also, it is easy to analyze, and it seems to be a good approximation for actual productions [13]. The Cobb–Douglas production function is expressed as:

$$Y = f(x)\exp(u) \qquad (2)$$

Eq. (2) can be further re-written as:

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

where Yi denotes the yield of the i the farmer; $X_{ij}$, the vector of inputs used in the production process; a, the constant term; $\alpha_j$, represent coefficients of inputs which are estimated from the model and $e_i$, the error term. Assuming that when the energy input is zero, the crop production is zero too, Eq. (3) is reformed to [15, 16, 17]:

$$\ln Y_i = \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \tag{4}$$

In the present case, n=7; therefore Eq. (4) can be expressed in the following form:

$$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + e_i \tag{5}$$

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

| Equipment /Inputs | Unit | Energy equivalents | Reference |
|---|---|---|---|
| A. Inputs | | | |
| 1.Human Labor | H | 1.96 | [18] |
| 2.Machinery | H | 62.7 | [4, 5] |
| 3.Diesel fuel | L | 47.8 | [19] |
| 4. Chemical Fertilizer | Kg | | |
| (a) Nitrogen | | 64.4 | [12, 20, 21, 22] |
| (b) Phosphate (P2O5) | | 11.6 | [7] |
| 5. Chemical | Kg | 114 | [7] |
| 6.Water for Irrigation | $M^3$ | 0.63 | [5, 17] |
| 7. Seed | Kg | 17.5 | [13] |
| B. Output | | | |
| 1. Maize | Kg | 17.5 | [13] |

Energy demand in agriculture can be divided into direct energy (DE), indirect energy (IDE), renewable energy (RE) and non-renewable energy (NRE). Direct energy is directly used at farms and on fields. Indirect energy, on the other hand, consists of the energy used in the manufacture, packaging and transport of fertilizers, pesticides and farm machinery [7]. The DE includes human labor, diesel fuel and water for Irrigation while the IDE covers chemical fertilizers, machinery, chemical and seeds used in the maize production. Renewable energy includes human labor, water for Irrigation, seeds and non-renewable energy consists of machinery, diesel fuel, chemical and chemical fertilizers. The effect of direct, indirect, renewable and non-renewable energies on production was also studied. For this purpose, Cobb–Douglas function was determined as Eqs(6) and (7):

$$\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i \tag{6}$$
$$\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \tag{7}$$

Where Yi is the *i*th the farm's yield; DE, IDE, RE and NRE are direct, indirect, renewable and non-renewable energies used for maize production, respectively. $\beta_i$ and $\gamma_i$ are coefficient of exogenous variables. Esq. (5) – (7) was estimated using ordinary least square technique.

The Marginal Physical Product (MPP) technique, based on the response coefficients of the inputs, was utilized to analyze the sensitivity of energy inputs on maize yield. The MPP which is a factor indicates the change in the output with a unit change in the factor input in question, keeping all other factors constant at their geometric mean level. The MPP of the various inputs was computed using the $\alpha_j$ of the various energy inputs as [14]:

$$MPP_{xj} = \frac{GM\,(Y)}{GM\,(X_j)} \times \alpha_j \qquad (8)$$

where $MPP_{xj}$ is marginal physical productivity of *j*th input; $\alpha_j$, regression coefficient of *j*th input; GM(Y), geometric mean of yield; and GM ($X_j$), geometric mean of j the input energy on per hectare basis. A positive value of MPP of any factor indicates that with an increase in input, production is increased and a negative value of MPP of any factor input indicates that additional units of inputs contribute negatively to production. Hence, it is better to keep the variable resource in surplus rather than utilizing it as a fixed resource [14]. In last part of the study the returns to scale of production was calculated. 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 elasticity's derived in the form of regression coefficients. If the sum of the coefficients is greater than unity, then it could be concluded as the increasing returns to scale, on the other hand if the latter parameter is less than unity then it is indicated as the decreasing returns to scale; and, if the result is unity it shows as the constant returns to scale [14]. Basic information on energy inputs and maize yields were entered into Excel's spreadsheet and SPSS 17.0 software. Modeling carried out using linear regression technique.

## RESULTS AND DISCUSSION

Table 2 shows the quantities of inputs used in maize and establishment of and their energy equivalences. Also Fig. 1 shows the distribution percent of the energy associated with the inputs. The total energy input for various processes in the maize production was calculated to be Total energy requirement for producing the maize crops was 26917.47 MJ $ha^{-1}$. Among the different energy sources N fertilizer was the highest energy consumer. The average use of the N fertilizer was 300 Kg $ha^{-1}$ in the maize production it is a common belief that increased use of fertilizer will increase the yield. Because of the high N fertilizer used in the production systems had the big values of 13717.20 MJ $ha^{-1}$. The other inputs applied in the growing process in the surveyed area and total energy inputs are shown in Table 2. The share of important energy inputs of total inputs energy are shown approximately in Figure 1.

**Table 2: Amounts of inputs, outputs and energy inputs and output in Maize production.**

| Inputs (unit) | Quantity per unit area (ha) | Total energy equivalent (MJ $ha^{-1}$) |
|---|---|---|
| A. Inputs | | |
| 1. Human labour (h) | 81.5 | 159.7 |
| 2. Machinery (h) | 17.7 | 1111.7 |
| 3. Diesel fuel (L) | 147.0 | 7026.6 |
| 4. Chemical fertilizers (kg) | 328.0 | 15051.2 |
| 5. Biocides (kg) | 4.8 | 547.2 |
| 6. Water for Irrigation (m3) | 4212.0 | 2653.6 |
| 7. Seed (kg) | 21.0 | 367.5 |
| The total energy input (MJ) | | 26917.5 |
| B. Output | | |
| 1. Maize (kg) | 5400.0 | 54639.9 |
| Total energy output (MJ) | | 54639.9 |

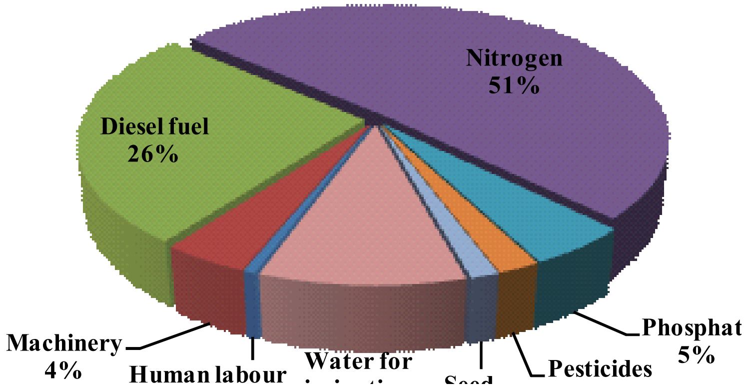

**Fig. 1. Distribution of inputs energy in Maize production.**

The energy input (Table 2) of chemical fertilizer (N and P) had the biggest share (56% approximately) of total energy inputs. After that diesel fuel, water for irrigation, machinery, pesticide, seed and human labor were 26, 10, 2, 4, 1 and 1 percent approximately respectively. The share of energy input as renewable and nonrenewable forms is illustrated in Fig. 2.

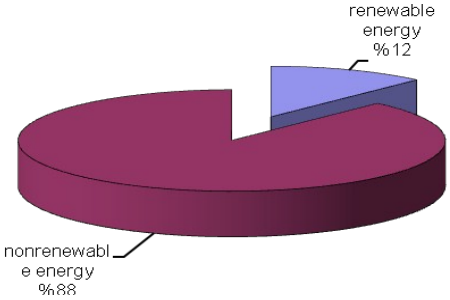

**Fig. 2. Share of renewable and nonrenewable forms**

The total consumed energy input could be classified as renewable energy (12%) and non-renewable energy (88%). This indicates that maize production depends mainly on non-renewable energy (diesel fuel and chemical fertilizers) in the studied area. Therefore, it is clear that non-renewable energy consumption was higher than that of renewable in maize production.

Regression results for Eq. (5) are shown in Table 3. For data used in this study, autocorrelation was tested using Durbin–Watson method [15, 23]. The Durbin–Watson value was found to be 1.190 for Eq. (5) which indicates that there was no autocorrelation at the 5% significance level in the estimated model. The $R^2$ value was determined as 0.97 for this equation, implying that around 0.97 of the variability in the energy inputs was explained by this model. The results of assessment of Cobb–Douglass function on each inputs in maize production indicates that the impact of each inputs differ in constitution of yield. As can be seen from Table 3, all exogenous variables had a positive impact on maize yield.

Among the variables included in the model, human labour and machinery energy was found as the most important variables which influence yield with 0.420 and 0.409 of elasticity and significantly contributed on the productivity at 1% level. This means that increasing 1% in human labour and machinery energy will result 0.420% and 0.409% increases in yield. This followed by chemical fertilizers and diesel fuel with 0.390 and 0.242 elasticity and significantly contributed on the productivity at 1% and 5% level respectively. Biocides and seed have little impact on yield with 0.052 and 0.040 of elasticity.

**Table 3: Econometric estimation results of inputs.**

| Endogenous variable: yield | Coefficient | *t*-ratio | MPP |
|---|---|---|---|
| Exogenous variables | | | |
| Model 1: $\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + e_i$ | | | |
| Human labour | 0.420 | $3.98^{*}$ | 3.64 |
| Machinery | 0.409 | $5.01^{*}$ | 5.57 |
| Diesel fuel | 0.242 | $2.49^{**}$ | 3.32 |
| Chemical fertilizers | 0.390 | $4.25^{*}$ | 2.54 |
| Biocides | 0.052 | 1.04 | 9.33 |
| Water for Irrigation | 0.142 | 0.18 | 5.14 |
| Seed | 0.040 | 0.69 | 6.02 |
| Durbin-Watson | 1.190 | | |
| $R^2$ | 0.97 | | |
| Return to scale | 1.695 | | |

$^{*,**}$ Indicates significance at 1% and 5%, respectively.

The sensitivity analysis of energy inputs for maize production also is showed in Table 3. As it can be seen, the MPP of biocides energy was biggest (9.33). This reveals that additional utilize of 1MJ for biocides energy would result in an increase in yield by 9.33 kg. Therefore additional use of biocides in unit area would result more yield. The MPP of the seeds, machinery and water for Irrigation was positive and was determined as 6.02, 5.57 and 5.14, respectively. This indicates that additional utilize of 1MJ for each of seeds, machinery and water for Irrigation energy would result in an increase in maize yield by 6.02, 5.57 and 5.14 kg, respectively. Hence, exogenous parameters with large sensitivity coefficients have a strong impact on the endogenous variable. This indicates which variables should be identified and measured most carefully to assess the state of the environmental system, and which environmental factors should be managed preferentially [24].

**Table 4. Econometric estimation results of direct, indirect, renewable and non-renewable energies.**

| Endogenous variable: yield | Coefficient | *t*-ratio | MPP |
|---|---|---|---|
| Exogenous variables | | | |
| Model 2: $\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i$ | | | |
| Direct energy | 0.635 | $4.72^{*}$ | 6.20 |
| Indirect energy | 0.577 | $4.53^{*}$ | 3.30 |
| Durbin-Watson | 1.981 | | |
| $R^2$ | 0.98 | | |
| Return to scale | 1.121 | | |
| Model 3: $\ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$ | | | |
| Renewable energy | 0.338 | $8.91^{*}$ | 4.21 |
| Non-renewable energy | 0.765 | $4.38^{**}$ | 3.12 |
| Durbin-Watson | 1.773 | | |
| $R^2$ | 0.99 | | |
| Return to scale | 1.103 | | |

$^{*,**}$ Indicates significance at 1% and 5%, respectively.

Regression coefficients of direct and indirect energies also renewable and non-renewable energies are shown in Table 4. Durbin–Watson values were calculated as 1.981and 1.773 for Eqs. (6), (7), respectively and the $R^2$ values were as 0.98 and 0.99 respectively. As can be seen from Table 4 both direct and indirect energy had positive impact on yield. Impact of direct energy (0.635) was more than that of indirect energy (0.577) and these impacts were significant at 1% level.

Impact of nonrenewable energy was 0.765 and impact of renewable energy was 0.338.

The MPP of direct, indirect, renewable and non-renewable energy also are show in Table 4 and were found to be 6.20, 3.30, 4.21 and 3.12, respectively. The sum of the regression coefficients of energy inputs was calculated as 1.695, 1.121 and 1.103 for Eqs. 5, 6 and 7, respectively. This implied that a 1% increase in the total energy inputs utilize would lead in 1.695%, 1.121% and 1.103% increase in the maize yield for this Eqs.

## CONCLUSION

The purpose of this study was to investigate influences of energy inputs and energy forms on output levels and evaluation of inputs sensitivity for maize production in Kermanshah province, Iran. Data were collected from 72 maize farms and the sample volume was determined by random sampling method. Total energy input was found to be 26.91GJ $ha^{-1}$ and total energy output was calculated as 54.63 GJ $ha^{-1}$. It was founded that the energy input of chemical fertilizer (N and P) with 56 percent had the biggest share of total energy inputs. After that diesel fuel, water for irrigation, machinery, pesticide, seed and human labor were 26, 10, 2, 4, 1 and 1 percent approximately respectively. The share of non-renewable energy was higher than that of renewable energy consumption. Econometric estimation results revealed that human labor had the highest impact (0.420) among other inputs and significantly contributed on yield at 1% level. The estimated MPP for Biocides energy was the biggest among inputs of energy. The MPP of direct, indirect, renewable and nonrenewable energy were found to be 6.2, 3.3, 4.21 and 3.12, respectively.

Optimal consumptions of chemical fertilizers and other major inputs would be useful not only in reducing negative effects to environment, but also in maintaining sustainability. Lack of soil analysis in the area leads to unconscious usage of chemical fertilizer. In order to reduce the chemical fertilizers consumption, using of Farmyard manure can be suggested. Also it is suggested that new policies are to be taken to reduce the negative effects of energy inputs such as plant, soil and climate pollution. Therefore, analysis of energy consumption is an important task.

## REFERENCES

[1] Anonymous., 2010. Department of statistics and information, Ministry of Jihad-e-Agriculture, Tehran, Iran. <http://www.maj.ir>.
[2] Taheri Garavand A, Asakereh A, Haghani K. Energy elevation and economic analysis of canola production in Iran a case study: Mazandaran province. International journal of environmental sciences 2010; 1(2): 236-243.
[3] Kizilaslan H. Input–output energy analysis of cherries production in Tokat Province of Turkey. Applied Energy 2009; 86:1354–1358.
[4] Erdal G, Esengun K, Erdal H, Gunduz O. Energy use and economical analysis of sugar beet production in Tokat Province of Turkey. Energy 2007; 32; 35–41.
[5] Esengun K, Gunduz O, Erdal G. Input–output energy analysis in dry apricot production of Turkey. Energy Conversion. Management 2007; 48: 592–598.
[6] Uhlin H. Why energy productivity is increasing: an I–O analysis of Swedish agriculture. Agric. Syst. 1998; 56: 443–465.
[7] Ozkan B, Akcaoz H, Fert C. Energy input-output analysis in Turkish agriculture. Renew Energy 2004; 29: 39-51.
[8] Kuesters J, Lammel J. Investigations of the energy efficiency of the production of winter wheat and sugar beet in Europe. Eur. J. Agron. 1999; 11: 35–43.
[9] Jianbo L. Energy balance and economic benefits of two agroforestry systems in northern and southern China. Agric. Ecosyst. Environ. 2006; 116: 255–262.
[10] Strapatsa AV, Nanos GD, Tsatsarelis CA. Energy flow for integrated apple production in Greece. Agric. Ecosyst. Environ. 2006; 116: 176–180.

[11] Uzunoz M, Akcay Y, Esengun K. Energy input–output analysis of sunflower seed (Helianthus annuus L.) oil in Turkey. Energy Source 2008; 3: 215–223.
[12] Mobtaker HG, Keyhani A, Mohammadi A, Rafiee S, Akram A. Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agric Ecosyst Environ 2010; 137(3–4): 367–72.
[13] Singh S, Singh S, Pannu CJS, Singh J. Optimization of energy input for raising cotton crop in Punjab. Energy. Convers. Manage. 2000; 41(17): 1851–61.
[14] Singh G, Singh S, Singh J. Optimization of energy inputs for wheat crop in Punjab. Energy Convers. Manage. 2004; 45(3):453–65.
[15] Mohammadi A, Omid M. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Appl Energy 2010; 87(1):191–6.
[16] Singh H, Mishra D, Nahar NM, Ranjan M. Energy use pattern in production agriculture of a typical village in arid zone India: part II. Energy Convers Manage 2003; 44(7): 1053–67.
[17] Hatirli SA, Ozkan B, Fert C. Energy inputs and crop yield relationship in greenhouse tomato production. Renew Energy 2006; 31(4):427–38.
[18] Bojaca CR, Schrevens E. Energy assessment of peri-urban horticulture and its uncertainty: case study for Bogota, Colombia. Energy 2010; 35(5): 2109-2118.
[19] Kitani O. Energy and biomass engineering. Cigr handbook of agricultural engineering. 1999. Vol. (v) ASAE. 330 pp.
[20] Pimentel D. Impacts of organic farming on the efficiency of energy use in agriculture. An organic center state of science review. 2006. Available in www.organic-center.org/reportfi les/ENERGY_SSR.pdf.
[21] Yilmaz I, Akcaoz H, Ozkan B. An analysis of energy use and input costs for cotton production in Turkey. Renewable Energy 2005; 30: 145-155.
[22] Mohammadi A, Rafiee S, Mohtasebi SS, Rafiee H. Energy inputs-yield relationship and cost analysis of kiwifruit production in Iran. Renewable Energy 2010; 35: 1071-1075.
[23] Hatirli SA, Ozkan B, Fert C. An econometric analysis of energy input–output in Turkish agriculture. Renewable Sustainable Energy Rev. 2005; 9(6):608–23.
[24] Drechsler M. Sensitivity analysis of complex models. Biol Conserv 1998; 86: 401–12.