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ASSESSMENT OF ENERGY REQUIREMENTS AND SENSITIVITY ANALYSIS OF INPUTS FOR WATERMELON PRODUCTION IN IRAN

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ABSTRACT: The aims of this study were to estimate the amount of input and output energy per unit area for watermelon production and investigate the relationship between yield and energy inputs. Also the Marginal Physical Product (MPP) method was used to analyze the sensitivity of energy inputs on watermelon yield and returns to scale of econometric model was calculated. For this purpose, a face to face questionnaire with 85 watermelon growers from Hamadan province, Iran was conducted. The results indicated that total energy inputs were 67764.16 MJ ha^{-1}. The energy use efficiency and specific energy of watermelon production were found as 1.20 and 1580.10 MJ tonnes^{-1}, respectively. The regression results revealed that energy inputs of chemical fertilizers, water for irrigation, farmyard manure and seed contributed significantly to the yield. Sensitivity analysis of inputs indicates that the MPP of seeds energy was very high. The MPP of machinery, and water for irrigation were obtained to be -2.198 and -0.545, respectively, showing that the use of machinery and water for irrigation energy is in excess for watermelon production in the area.

Keywords*:* Specific energy, Econometric model, Seed energy, Watermelon

INTRODUCTION

Watermelon (Citrullus lanatus) is a member of the cucurbit family (Cucurbitaceae). The crop is grown commercially in areas with long frost-free warm periods [1]. Watermelon is utilized for the production of juices, nectars and fruit cocktails, etc. [2]. Management of plant pests is essential during the production period. The fruit are harvested by hand, with the most experienced workers doing the cutting (removal of the fruit from the vine) and the others loading the bins or trucks. The watermelon fruit is 93% water, with small amounts of protein, fat, minerals, and vitamins. The major nutritional components of the fruit are carbohydrates, vitamin A, and lycopene, an anticarcinogenic compound found in red flesh watermelon. Lycopene may help reduce the risk of certain cancers, such as prostate, pancreas, and stomach [1]. Iran is the 3th largest producer of watermelon in the world after China and Turkey, respectively [3]. In 2008, Iran produced about 3,400,000 tonnes of watermelon in 135000 hectares. Hamadan province is a one of important watermelon producers in Iran. In 2008, for example, the crop was planted in 13717 ha in this province [4].

The use of the energy resources has increased markedly with the advancement in the technology and general agricultural developments. Traditional, low energy farming is being replaced by modern systems, which require more energy use [5]. An efficient use of energy is required to produce sustainable food. Energy input–output analysis in agricultural systems has been widely used to assess the efficiency and the environmental impact [6].

Efficient use and study impacts of these energies on crop production help to achieve increased production and productivity and help the economy, profitability and competitiveness of agricultural sustainability of rural communities [7]. Nowadays, utilization of integrated production methods are considered as a sustainable way to reduce production costs, to efficient use of human labour and to protect the energy budgets for agricultural production [8].

Numerous research studies have been conducted on energy and economic analysis to determine the energy efficiency or energy balance between the input and the output of crop production [9-15]. However, very little research has been done to investigate watermelon production energy use efficiency and however, no studies have been published on the energy inputs – yield relationship and sensitivity analysis of inputs in watermelon production. Canakci et al. [16] surveyed energy consumption in the production of some field crops and vegetable production in Turkey. Their investigation insists of wheat, cotton, maize, sesame, tomato, melon and watermelon. Mohammadi and Omid [17] studied economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. They calculated total energy consumption, energy use efficiency, specific energy and energy forms of direct, indirect, non-renewable and renewable.

The main aims of this study were to determine energy use and evaluate the relationship between inputs and output in watermelon production in Hamadan, Iran. Also the Marginal Physical Product (MPP) method was used to analyze the sensitivity of energy inputs on watermelon yield and returns to scale of Cobb–Douglas function was calculated.

MATERIALS AND METHODS

Data were collected from 85 watermelon farms using a face to face questionnaire in May 2009. Fifteen villages were chosen to represent the whole study area (Hamedan province). In addition to the survey results, the results of previous studies were also used in this study. The data collected belonged to the production period of 2007–2008. The province is located in the west of Iran, within 59° 33' and 49° 35' north latitude and 34° 47' and 34° 49' east longitude [4].

Sample farms were randomly selected from the study province. The size of each sample was determined using Eq. (1) [18]:

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

where n is the required sample size; N is the number of holdings in target population; s is the standard deviation; t is the t value at 95% confidence limit (1.96); and d is the acceptable error (permissible error 5%). Thus calculated sample size in this study was 85.

Energy equivalents' coefficients were calculated based on previous studies. Table 1 showed energy equivalents were used for estimating inputs and output energies in watermelon production.

The energy use efficiency (energy ratio), the energy productivity, the specific energy and net energy gain were calculated based on the energy equivalents (Table 1) and following functions, [21,22]:

$$\text{Energy use efficiency} = \frac{\text{Energy Output (MJ ha}^{-1}\text{)}}{\text{Energy Input (MJ ha}^{-1}\text{)}} \qquad (2)$$

$$\text{Energy productivity} = \frac{\text{Watermelon output (kg ha}^{-1}\text{)}}{\text{Energy Input (MJ ha}^{-1}\text{)}}$$

(3)

$$\text{Specific energy} = \frac{\text{Energy input (MJha}^{-1}\text{)}}{\text{Watermelon output (tha}^{-1}\text{)}} \tag{4}$$

$$\text{Net energy} = \text{Energy output (MJha}^{-1}\text{)} - \text{Energy input (MJha}^{-1}\text{)} \tag{5}$$

Energy use in agriculture can be divided into direct and indirect, renewable and non-renewable energies [11]. Indirect energy included energy embodied in fertilizers, farmyard manure, chemical, seed and machinery while direct energy covered human labour, diesel fuel, and water for irrigation used in the watermelon production process. Non-renewable energy consists of diesel, chemicals, fertilizers and machinery energies and renewable energy includes human labour, seeds, farmyard manure and water for irrigation energies. For determine relationship between energy inputs and yield, different mathematical functions were tried, but several authors used Cobb–Douglas function, because this function produced better results among the others [17,23,24]. The Cobb–Douglas production function is expressed as follows [25]:

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

This function can be linearized and further expressed as:

$$\ln \mathrm{Y_i} = a + \sum\nolimits_{j=1}^{n} \alpha_j \ln (\mathrm{X_{ij}}) + e_i \qquad I = 1,2,\ ...,n \tag{7}$$

where Y_i is the yield of the ith farmer, X_{ij}, the inputs' equivalent energies used in the production process, a is the constant term, α_j , coefficients of inputs which are estimated from the model and e_i is the error term. In this study, it is assumed that if there is no input energy, the output energy is also zero. The same assumption also was made by other authors [17,24]. Therefore Eq. (7) reduces to:

$$\ln \mathrm{Y_i} = \sum_{j=1}^{n} a_j \ln(\mathrm{X_{ij}}) + e_i \tag{8}$$

in this study Eq. (8) expressed in the flowing form:

$$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + c \tag{9}$$

where X_1, X_2, X_3,…, X_8 expressed respectively human labour, machinery, diesel fuel, chemical fertilizers, Farmyard manure, chemicals, water for irrigation and seed energies. In addition to determine impact of each input in yield, the relationship between direct and indirect energy also renewable and non-renewable energy on yield were investigated. For this purpose, Cobb–Douglas function was specified in the following form:

$$\ln Y_i = \beta_0 + \beta_1 \ln DE + \beta_2 \ln IDE + e_i \tag{10}$$

$$\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \tag{11}$$

where Y_i is the ith farm's yield, β_i and γ_i are the coefficients of exogenous variables. DE, IDE, RE and NRE are direct, indirect, renewable and non-renewable energy forms respectively. Eqs. (9)-(11) were estimated using ordinary least square technique (OLS).

In the last part of the study The Marginal Physical Product (MPP) method, was used to analyze the sensitivity of energy inputs on watermelon yield and returns to scale of Cobb–Douglas function was calculated. The sensitivity analysis of an input imposes the change in the output level with a unit change in the input in model, assuming that all other inputs are constant at their geometric mean level. The MPP of the various inputs was computed using the α_j of the various energy inputs as [26]:

$$MPP_{xj} = \frac{GM\,(Y)}{GM\,(X_j)} \times \alpha_j \qquad (12)$$

where MPP_{xj} is MPP of jth input; α_j, regression coefficient of jth input; GM(Y), geometric mean of yield; and $GM(X_j)$, geometric mean of jth input energy on per hectare basis. If the value of MPP of any variable is positive, this means that with an increase in input, production is increasing and if the value of MPP of any variable is negative, this means that additional units of inputs are contributing negatively to production. In the Cobb–Douglas production function, returns to scale 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 ($\sum_{i=1}^{n} \alpha_i > 1$), this means that the increasing returns to scale, and if the latter parameter is less than unity ($\sum_{i=1}^{n} \alpha_i < 1$), this means 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 [26].

Basic information on energy inputs and watermelon yield were entered into Excel's spreadsheets and use Shazam version 9.0 software for simulating.

RESULTS AND DISCUSSION

Analysis of input–output energy use in watermelon production

Inputs used and output in watermelon production in the area of survey, and their energy equivalents with output energy rates and their equivalents are illustrated in Table 2. Total energy consumed in various farm operations during watermelon production was 67764.16 MJ ha^{-1}. Chemical fertilizer consumes 44.83% of total energy inputs followed by diesel energy 32.19% during production period. Diesel energy was mainly consumed for irrigation and land preparation. From Table 2, it is shown that seeds were the least demanding energy input for watermelon production with 3.08 MJ ha^{-1}, followed by chemicals by 273.6 MJ ha^{-1} (0.40%). The shares of other inputs are presented in Table 1 and 2.

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

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Reference
A. Inputs			
1. Human labour	h	1.96	[12]
2. Machinery	h	62.7	[19]
3. Diesel fuel	L	56.31	[19]
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		66.14	[20]
(b) Phosphate (P_2O_5)		12.44	[20]
I Potassium (K_2O)		11.15	[20]
(d) Sulphur (S)		1.12	[14]
5. Farmyard manure	kg	0.30	[19]
6. Chemicals	kg	120	[19]
9. Water for irrigation	m^3	1.02	[14]
10. Seeds (watermelon)	kg	1.90	[16]
B. Outputs			
1. Watermelon	kg	1.90	[16]

Table 2 : Amounts of inputs and output in watermelon production.

Quantity (inputs and outputs)	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})	Percentage of the total energy input (%)
A. Inputs			
1. Human labour (h)	654.54	1282.90	1.89
2. Machinery (h)	21.15	1326.11	1.96
3. Diesel fuel (L)	387.35	21811.68	32.19
4. Chemical fertilizers (kg)	898.69		44.83
(a) Nitrogen (N) (kg)	379.76	25117.33	37.07
(b) Phosphate (P_2O5) (kg)	280.13	3484.82	5.14
(c) Potassium (K_2O) (kg)	150.37	1676.63	2.47
(e) Sulphur (S) (kg)	88.43	99.04	0.15
5. Farmyard manure (kg)	8580.35	2574.11	3.80
6. Chemicals (kg)	2.28	273.6	0.40
7. Water for irrigation (m^3)	9916.53	10114.86	14.93
8. Seeds (watermelon) (kg)	1.62	3.08	0.00
Total energy input (MJ)		67764.16	100
B. Outputs			
1. watermelon (kg)	42885.90	81483.21	
Total energy output (MJ)		81483.21	

The energy input and output, yield, energy use efficiency, specific energy, energy productivity and net energy of watermelon production in the Hamadan province are showed in Table 3. Average annual yield of farms investigated was 42885.90 kg ha^{-1} and calculated total energy output was 81483.21 MJ ha^{-1}. Energy use efficiency (energy ratio) was calculated as 1.20. The average energy productivity of farms was 0.63. This means that 0.63 outputs were obtained per unit energy. The specific energy and net energy of watermelon production were 1580.10 MJ $tones^{-1}$ and 13719.05 MJ ha^{-1}, respectively. In previous investigations, Canakci et al. [16] concluded that total energy input, energy use efficiency and specific energy for watermelon production were 14192.9 MJ ha-1, 2.0, and 0.97 MJ kg-1 , respectively. Strapatsa et al. [9] reported the energy productivity and specific energy as 0.42 kg MJ-1 and 2.50 MJ kg-1, respectively, for apple production in Greece.

Table 3 : Energy input–output ratio and energy input in the form of direct, indirect, renewable and non-renewable in watermelon production.

Items	Unit	watermelon
Energy input	MJ ha^{-1}	67764.16
Energy output	MJ ha^{-1}	81483.21
Yield	kg ha^{-1}	42885.90
Energy use efficiency	-	1.20
Specific energy	MJ $tonnes^{-1}$	1580.10
Energy productivity	kg MJ^{-1}	0.63
Net energy	MJ ha^{-1}	13719.05

Figure 1 shows the distribution of total energy input as direct (DE), indirect (IDE), renewable (RE) and non-renewable (NRE) forms. As it can be seen from the Figure1, the total energy input consumed could be classified as direct energy, indirect energy, renewable energy and non-renewable energy that share of each of them in watermelon production is 49%, 51%, 20.62% and 79.38% respectively. Several authors reported the direct, indirect, renewable and non-renewable energy forms for different crops such as Esengun et al. [12] for apricot, Mohammadi et al. [14] for kiwifruit and Kizilaslan [18] for cherries.

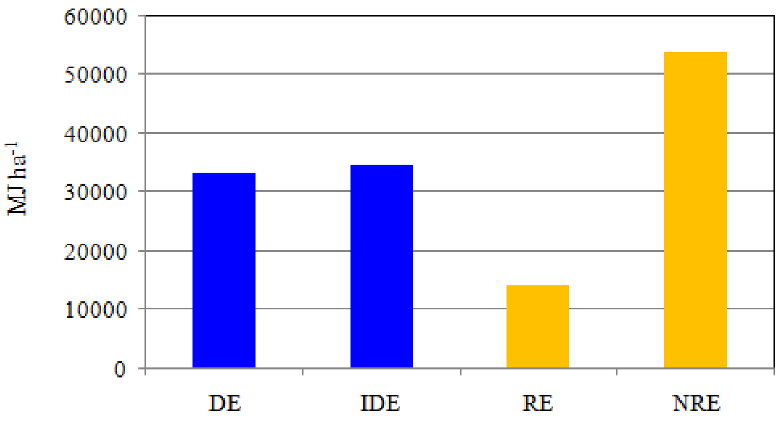

Figure 1. Distribution of different forms of energy in watermelon production.

Econometric model estimation of energy inputs for watermelon production

For estimating the relationship between energy inputs and yield the Cobb–Douglas function was used. Therefore watermelon yield (endogenous variable) was assumed to be a function of human labour, machinery, diesel fuel, chemical fertilizers, farmyard manure, chemicals, water for irrigation and seed energy (exogenous variables). The values of coefficients α_i appearing in Eq. (9), β_i in Eq. (10) and γ_i in Eq. (11) were calculated for the watermelon production (Table 4). The corresponding R2 values were also determined. Autocorrelation for Eqs 9- 11 have tested with Durbin–Watson test [27].

In this study value of Durbin–Watson for Eq. (9) was found 2.33 that revealed there was no autocorrelation at the 5% significance level in the estimated model. For this model value of R^2 was 0.99 (Table 4).

Table 4 : Econometric estimation results of inputs.

Endogenous variable: yield	Coefficient	*t*-ratio	MPP
Exogenous variables			
Model 1: $\ln Y_i = a_0 + a_1 \ln X_1 + a_2 \ln X_2 + a_3 \ln X_3 + a_4 \ln X_4 + a_5 \ln X_5 + a_6 \ln X_6 + a_7 \ln X_7 + a_8 \ln X$			
Human labour	0.03	0.428	1.175
Machinery	-0.06	-0.396	-2.198
Diesel fuel	0.02	0.206	0.317
Chemical fertilizers	0.19	2.683^{*}	0.334
Chemicals	0.08	1.378	14.874
Water for irrigation	-0.11	-2.013^{**}	-0.545
Farmyard manure	0.27	1.833^{***}	5.025
Seeds	0.39	5.538^{*}	708.857
Durbin-Watson	2.33		
R^2	0.99		
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	0.810		

*, **, *** Indicates significance at 1% ,5% and 10% level, respectively.

Regression result for Eq. 9 is shown in Table 4. As shown in this Table, the contribution of chemical fertilizers and seed energy are significant at the 1% level and contribution of water for irrigation energy is significant at the 5% level.

Also contribution of farmyard manure energy is significant at the 10% level. Among the variables included in the model, seed energy was found as the most important variable that influences yield with 0.39 of elasticity. This means that increasing 1% in seed energy will result 0.39% increase in yield. Elasticity for machinery and water for irrigation are negative with -0.06 and -0.11 respectively. Hatirli et al. [24] research has been focused on the influence of production inputs on yield of greenhouse tomato. Their results have shown, especially factors which are human labour, fertilizer, chemicals, machinery and water energy are influence significantly on yield of greenhouse tomato. Mohammadi and Omid [17] reported that, for greenhouse cucumber production, elasticities of human labour, machinery, diesel fuel, farmyard manure, chemicals, water for irrigation and electricity are significant and human labour energy had the highest impact among the other inputs in yield.

Regression coefficients of direct and indirect energies also renewable and non-renewable energies are shown in Table 5. The regression coefficient of indirect energy and Non-renewable energy were positive and statistically significant at 1% level. Durbin–Watson values were calculated as 2.28 and 2.33 for Eqs. (10), (11), respectively and the R^2 values for both Eqs were as 0.99 (Table 5). Hatirli et al. [27] founded that impact of non-renewable energy on output level was significant whereas, renewable energy had insignificant impact on yield.

Sensitivity analysis of various energy inputs on the production of watermelon

The sensitivity analysis of energy inputs are showed in table 4. As it could be seen in Table 4, the MPP of seeds energy was very high (708.857). This reveals that additional utilize of 1MJ for seeds energy would result in an increase in yield by 708.857 kg. Therefore additional use of seed in unit area, and intensive farming, would result raising productivity in present condition. Also the MPP of the chemicals, farmyard manure, human labour and total chemical fertilizers was positive and was determined as 14.874, 5.025, 1.175 and 0.334, respectively. This indicates that additional utilize of 1MJ for each of the chemicals, farmyard manure, human labour and total chemical fertilizers energy would result in an increase in yield by 14.874, 5.025, 1.175 and 0.334 kg, respectively. The MPP of machinery and water for irrigation was negative (-2.198 and -0.545). This means that additional units of these inputs are contributing negatively to production. Singh et al. [23] calculated the sensitivity of energy inputs on wheat productivity for five agro-climate zones in India. They reported the MPP of electrical energy (2.737) was very high due to the use of canal water.

Table 5 : Econometric estimation results of direct, indirect, renewable and non-renewable energies.

Endogenous variable: energy output	Coefficient	*t*-ratio	MPP
Exogenous variables			
Model 2: $\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i$			
Direct energy	-0.06	-1.030	-0.203
Indirect energy	0.43	8.002^*	0.652
Durbin-Watson	2.28		
R^2	0.99		
Return to scale ($\sum_{i=1}^{n} \beta_i$)	0.370		
Model 3: $\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$			
Renewable energy	-0.08	-1.222	-0.279
Non-renewable energy	0.44	7.598^*	0.655
Durbin-Watson	2.33		
R^2	0.99		
Return to scale ($\sum_{i=1}^{n} \gamma_i$)	0.360		

* Significance at 1% level.

The sensitivity analysis of energy inputs as direct, indirect, renewable and non-renewable forms are showed in table 5. The MPP of direct energy and renewable energy was negative, while, the MPP of indirect energy and non-renewable energy was positive. This indicates that with an additional use of 1 MJ of each of the indirect and non-renewable energy would lead to an additional increase in yield by 0.652 and 0.655 kg, respectively. The sum of the regression coefficients of energy inputs was calculated as 0.810, 0.370 and 0.360 for Eqs. 9, 10 and 11, respectively. This implied that a 1% increase in the total energy inputs utilize would lead in 0.810%, 0.370% and 0.360% increase in the watermelon yield for this Eqs. The lower value than unity revealed a decreasing return to scale.

CONCLUSIONS

In this study, relationship between energy inputs and yield and sensitivity analysis of energy inputs for watermelon production were investigated in Hamadan province. As a result of calculation of the energy budget, the average of energy input in watermelon production was to be 67764.16 MJ ha^{-1}. The energy input of chemical fertilizer has the biggest share within the total energy inputs followed by diesel fuel. Approximately 79.38% of total energy input from non-renewable and only 20.62% from renewable energy forms. Regression result between energy inputs and yield showed that contribution of chemical fertilizers, seed, water for irrigation and farmyard manure are significant on output level. The impact of seed energy was found as the most important variable that influences yield with 0.39 of elasticity. Sensitivity analysis indicates that the MPP of seeds, chemicals, farmyard manure, human labour and total chemical fertilizers was positive and the MPP of machinery, and water for irrigation was negative. The sum of the regression coefficients of energy inputs was calculated as 0.810, 0.370 and 0.360 for Eqs. 9, 10 and 11, respectively. High consumption of chemical fertilizers is expected to compensate for the soil nutrients deficiency. Therefore, using proper management of energy sources and crop rotation such as growing the leguminous plants which stabilize the nitrogen in the soil can decrease its consumption.

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