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Econometric Model Estimation and Sensitivity Analysis of Inputs for Mandarin Production in Mazandaran Province of Iran

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Abstract: This study examines energy consumption of inputs and output used in mandarin production, and to find relationship between energy inputs and yield in Mazandaran, Iran. Also the Marginal Physical Product (MPP) method was used to analyze the sensitivity of energy inputs on mandarin yield and returns to scale of econometric model was calculated. For this purpose, the data were collected from 110 mandarin orchards which were selected based on random sampling method. The results indicated that total energy inputs were 77501.17 MJ/ha. The energy use efficiency, energy productivity and net energy of mandarin production were found as 0.77, 0.41 kg/MJ and -17651.17 MJ/ha. About 41% of the total energy inputs used in mandarin production was indirect while about 59% was direct. Econometric estimation results revealed that the impact of human labor energy (0.37) was found the highest among the other inputs in mandarin production. The results also showed that direct, indirect and renewable and non-renewable, energy forms had a positive and statistically significant impact on output level. The results of sensitivity analysis of the energy inputs showed that with an additional use of 1 MJ of each of the human labor, farmyard manure and chemical fertilizers energy would lead to an increase in yield by 2.05, 1.80 and 1.26 kg, respectively. The results also showed that the MPP value of direct and renewable energy were higher.

Key words: Energy use efficiency, human labor, mandarin yield, sensitivity

INTRODUCTION

In recent years there has been increasing public debate on the effects of agricultural production on the environment. One major concern of the debate is the use of energy in agriculture. Owing to the high energy consumption during the production of agricultural inputs, in particular non-renewable inputs, it is often questioned as to whether agricultural production is still energy efficient (Kuesters and Lammel, 1999). Therefore, It can be expected that energy budget would be useful not only for reducing negative effects to environment, human health, maintaining sustainability and decreasing production costs, but also for providing higher energy use efficiency (Banaeian and Zangeneh, 2011). The energy budget provides sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs. Estimating these functional forms is very useful in terms of determining elasticities of inputs on yield and production (Hatirli *et al*., 2006).

Several studies have been conducted on the use of energy in agriculture with respect to efficient and economic uses of energy for sustainable production (Ozkan *et al*., 2004a, b; Yilmaz *et al*., 2005; Erdal *et al*., 2007; Esengun *et al*., 2007; Mohammadi *et al*., 2008; Kizilaslan, 2009; Zangeneh *et al*., 2010; Namdari, 2011). But little attention has been given to the relationships between input energy and yield using functional forms in these research studies where energy use in agriculture was examined. Hatirli *et al*. (2006) for greenhouse tomato, Mohammadi *et al*. (2010) for kiwifruit, Rafiee *et al*. (2010) for apple, Mobtaker *et al*. (2010) for barley, Banaeian and Zangeneh (2011) for walnut production, investigated energy inputs and crop yield relationship to develop and estimate an econometric model. Although many studies are conducted on energy use in agricultural crops, there are not any studies on the energy analysis of mandarin production in Iran.

The aims of this research were to develop and estimate an econometric model for mandarin production in Mazandaran province of Iran. Once estimated, the model is expected to show the relationship between energy inputs and yield providing energy input elasticities on yield. Furthermore, this study seeks to analyze the effect of indirect and direct energy consumption on yield

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

Particulars	Unit	Energy equivalent (MJ/unit)	Reference
A. Inputs			
1. Human labor	h	1.96	(Ozkan *et al*., 2004a)
2. Machinery	h	62.70	(Ozkan *et al*., 2004a)
3. Diesel fuel	l	56.31	(Mohammadi *et al*., 2010)
4. Chemical fertilizers	kg		
Nitrogen (N)		66.14	(Mohammadi *et al*., 2010)
Phosphate (P_2O_5)		12.44	(Mohammadi *et al*., 2010)
Potassium (K_2O)		11.15	(Mohammadi *et al*., 2010)
5. Farmyard manure	kg	0.30	(Mohammadi *et al*., 2010)
6. Chemicals	kg	120	(Mohammadi *et al*., 2010)
7. Electricity	kWh	11.93	(Ozkan *et al*., 2004a)
8. Water for irrigation	m^3	1.02	(Mohammadi *et al*., 2010)
B. Outputs			
1. Mandarin	kg	1.90	(Ozkan *et al*., 2004a)

using functional form. In addition to these, it was also an aim to calculate energy use efficiency, energy productivity, and specific energy used in mandarin production.

MATERIALS AND METHODS

In this study, mandarin growers were surveyed in 110 orchards from Mazandaran province, Iran. The Mazandaran province is located in the north of Iran, within 31º47′ and 38º05′ North latitude and 50º34′ and 56º14′ East longitude. The size of sample of each stratification was determined Neyman technique (Rafiee *et al*., 2010). Data were collected by using a face-to-face questionnaire performed. The inputs such as fuel, electricity, machinery, water for irrigation, chemical fertilizer and chemicals take significant share of the energy supplies in the production system of modern agriculture (Hatirli *et al*., 2006). The amounts of input were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. Energy equivalents' coefficients were calculated based on previous studies (Table1). Table 1 showed energy equivalents were used for estimating inputs and output energies in mandarin production.

The energetic efficiency of the agricultural system has been evaluated by the energy ratio between the output and the inputs (Zangeneh *et al*., 2010). Some energy parameters in mandarin production such as: the energy use efficiency (energy ratio), the energy productivity, the specific energy and net energy gain, were calculated based on the following functions (Ozkan *et al*., 2004a):

$$\text{Energy use efficiency} = \text{Energy output (MJ/ha)} / \text{Energy input (MJ/ha)} \quad (1)$$

$$\text{Energy productivity} = \text{Mandarin output (kg/ha)} / \text{Energy input (MJ/ha)} \quad (2)$$

$$\text{Specific energy} = \text{Energy input (MJ/ha)} / \text{Mandarin output (kg/ha)} \quad (3)$$

$$\text{Net energy} = \text{Energy output (MJ/ha)} / \text{Energy input (MJ/ha)} \quad (4)$$

In order to analyze the relationship between energy inputs and energy output, different functions were investigated and with respect to the experiments related to selecting optimized functions (Mohammadi *et al*., 2010). Several authors used Cobb-Douglas function, because this function produced better results among the others (Hatirli *et al*., 2006; Rafiee *et al*., 2010; Mohammadi *et al*., 2010; Mobtaker *et al*., 2010; Banaeian and Zangeneh, 2011). The Cobb-Douglas production function is expressed as follows (Gujarati, 1995):

$$Y = f(x)\exp(\mu) \quad (5)$$

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 (Hatirli *et al*., 2006; Rafiee *et al*., 2010; Mohammadi *et al*., 2010). Eq. (6) is expanded in accordance with the assumption that the yield is a function of energy inputs (Mohammadi and Omid, 2010):

$$\ln Y_i = a_1 \ln X_1 + a_2 \ln X_2 + a_3 \ln X_3 + a_4 \ln X_4 + a_5 \ln X_5 + a_6 \ln X_6 + a_7 \ln X_7 + a_8 \ln X_8 + e_i \quad (6)$$

where, X_i (i = 1, 2 ,…, 9) stand for input energies from human labor (X_1), machinery (X_2), diesel fuel (X_3), farmyard manure (X_4), chemical fertilizer (X_5), chemicals (X_6), electricity (X_7) and water for irrigation (X_8). With respect to this pattern, by using (6), the impact of the energy of each input on the output energy was studied. In addition the impacts of Direct Energy (DE) and Indirect Energy (IDE) items and Renewable Energy (RE) and Non-renewable Energy (NRE) items on the yield were investigated. Indirect energy included energy embodied in fertilizers, farmyard manure, chemical and machinery while direct energy covered human labor, diesel fuel, electricity and water for irrigation used in the mandarin production process. Non-renewable energy consists of diesel, chemicals, fertilizers and machinery energies and

Table 2: Amounts of inputs and output in mandarin production

Inputs (unit)	Quantity per unit area (ha)	Total energy Equivalent (MJ/ha)
A. Inputs		
1.Human labor (h)	1386.00	2716.56
2.Machinery (h)	72.00	4514.40
3.Diesel fuel (l)	330.00	18582.30
4.Chemical fertilizer (kg)		17474.85
Nitrogen	135.00	8928.90
Phosphate	415.00	5992.60
Potassium	229.00	2553.35
5.Farmyard manure (kg)	20500.00	6150.00
Chemicals (kg)		3777.60
Pesticides	5.00	995.00
Fungicides	3.60	331.20
Herbicides	10.30	2451.40
6.Electricity (kWh)	542.00	6466.06
7.Water for irrigation (m^3)	17470.00	17819.40
Total energy input (MJ)	-	77501.17
B. Output		
1.Mandarin (kg)	31500.00	59850.00

renewable energy includes human labor, farmyard manure and water for irrigation energies. For this purpose, Cobb-Douglas function was specified in the following form:

$$\ln Y_i = \beta_0 + \beta_1 \ln DE + \beta_2 \ln IDE + e_i \qquad (7)$$

$$\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \qquad (8)$$

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.

In the Cobb-Douglas production function, If the sum of the coefficients (returns to scale) is greater than unity, this means that the increasing returns to scale, and if the latter parameter is less than unity, this means that the decreasing returns to scale; and, if the result is unity, it shows that the constant returns to scale (Singh *et al*., 2004).

In the last part of the research, the Marginal Physical Productivity (MPP) method, based on the response coefficients of the inputs was utilized to analyze the sensitivity of energy inputs on mandarin yield. 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 (Mobtaker *et al*., 2010). A positive value of MPP of any input variable indicates that the total output is increasing with an increase in input; so, one should not stop increasing the use of variable inputs so long as the fixed resource is not fully utilized. A negative value of MPP of any variable input identifies that additional unit of input starts to diminish the total output of previous units; therefore, it is better to keep the variable resource in surplus rather than utilizing it as a fixed resource (Banaeian and Zangeneh, 2011). The MPP of the various inputs was calculated using the α_j of the various energy inputs as follow (Singh *et al*., 2004):

$$MPP_{xj} = [GM (Y) / GM (X_j)] \times \alpha_j \qquad (9)$$

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.

RESULTS AND DISCUSSION

Analysis of input-output energy use in mandarin production: Table 2 shows the physical inputs used and output in mandarin orchards in the surveyed area, and their energy equivalents with output energy rates and their equivalents. Also, in Fig. 1, distribution of the anthropogenic energy input ratios in the production of mandarins are given.

As it can be seen in the Table 2, total energy used in various farm operations during mandarin production was 59850 MJ/ha. Diesel energy consumes about 24% of total energy followed by chemical fertilizer (about 23%) and water for irrigation (about 23%) during production period (Fig. 1). In addition to these inputs energy consumptions, ratios of farmyard manure, electricity, machinery, chemicals and human labor, within total input energy were 8, 8, 6, 5 and 3%, respectively. The diesel energy was mainly utilized for pumping water and operating tractors for performing the various farm operations such as land preparation, cultural practices and transportation. Mohammadi *et al*. (2008) for potato production, Ozkan *et al*. (2004 a) for orange, mandarin and lemon productions, Yilmaz *et al*. (2005) for cotton, Esengun *et al*. (2007) for stake-tomato and Banaeian *et al*. (2011) for greenhouse strawberry reported that the highest energy input is provided by diesel fuel followed by fertilizers.

Average annual yield of orchards investigated was 31.50 tons/ha. The energy use efficiency, specific energy, energy productivity and net energy gain of mandarin production in the Mazandaran province are tabulated in Table 3. Energy use efficiency (energy ratio) was calculated as 0.77. In previous investigations, Ozkan *et al*. (2004a) in Turkey calculated energy ratio as

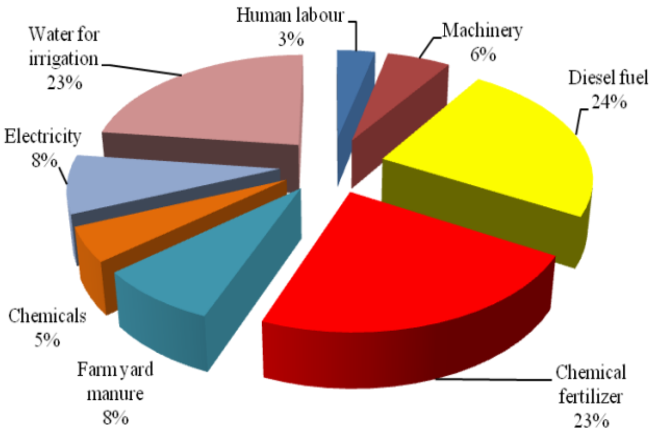

Fig. 1: The anthropogenic energy input ratios in the production of mandarins

Table 3: Some energy parameters in mandarin production.

Items	Unit	Mandarin	Share (%)
Energy use efficiency	-	0.77	-
Energy productivity	Kg/MJ	0.41	-
Specific energy	MJ/kg	2.46	-
Net energy	MJ/ha	-17651.17	-
Direct energy [a]	MJ/ha	45584.32	58.82
Indirect energy [b]	MJ/ha	31916.85	41.18
Renewable energy [c]	MJ/ha	26685.96	34.43
Non-renewable energy [d]	MJ/ha	50815.21	65.57
Total energy input [e]	MJ/ha	77501.17	100

a: Includes human labor, diesel fuel, water for irrigation, electricity; b: Includes chemical fertilizers, farmyard manure, chemicals, machinery; c: Includes human labor, farmyard manure, water for irrigation; d: Includes diesel fuel, electricity, chemicals , chemical fertilizers, machinery; e: Figures in parentheses indicate percentage of total energy input

1.17 for mandarin production. Ozkan *et al.* (2004b) for greenhouse paprika (0.99) and for greenhouse cucumber (0.76), Esengun *et al.* (2007) for tomato (0.80), Kizilaslan (2009) for cherries (0.96) and Zangeneh *et al.* (2010) for potato (0.96) reported energy use efficiency as less than unity.

The specific energy of mandarin production was 2.46 MJ/kg (Table 3). The energy productivity of mandarin production (reciprocal of the specific energy) was 0.41 kg/MJ. This means in mandarin production 0.41 kg output was obtained per unit energy (MJ). Calculation of energy productivity rate is well documented in the literature such as stake-tomato (1.0) (Esengun *et al.*, 2007), cotton (0.06) (Yilmaz *et al.*, 2005), sugar beet (1.53) (Erdal *et al.*, 2007) and tomato (0.32 and 0.27) (Zangeneh *et al.*, 2010).

The net energy in mandarin production was -17651.17 MJ/ha (Table 3). Therefore, it is concluded that in mandarin production in Mazandaran province, energy has been lost. Similarly, Zangeneh *et al.* (2010) for potato, Mohammadi and Omid (2010) for greenhouse cucumber, Banaeian *et al.* (2011) for greenhouse strawberry reported negative value for net energy. The negative value for the net energy (less than zero) in mandarin production has several reasons. Based on the structure of farming system and the level of technology in citrus orchards of Mazandaran province, such as using diesel fuel for pumping water, practicing traditional method of irrigation, wasting chemical fertilizers, this negative value is reasonable.

As it can be seen from Table 3, 65.57% of total energy input resulted from non-renewable and 34.43% from renewable energy and 58.82% from direct energy and 41.18% indirect energy. Intensity of non-renewable energy consumption resulted from diesel fuel and chemical fertilizer use in production.

The sensitivity analysis and econometric results: Relationship between energy inputs and yield was estimated using Cobb-Douglas production function for the mandarin crop. Since the coefficient of variables in this function is in log form also represents elasticities (Mobtaker *et al.*, 2010). The values of coefficients α_i appearing in Eq. (6), β_i in Eq. (7) and γ_i in Eq. (8) were calculated for the watermelon production (Table 4). The corresponding R^2 values were also determined. Autocorrelation for Eq. (6-8) have tested with Durbin-Watson test (Hatirli *et al.*, 2006).

For data used in this study, the Durbin-Watson value was found to be 1.57 for Eq. (6) (Model 1) which indicates that there was no autocorrelation at the 5%

Table 4: Econometric estimation results of inputs.

Variables	Coefficient	*t*-ratio	MPP
Model 1: $\ln Y_i = a_1 \ln X_1 + a_2 \ln X_2 + a_3 \ln X_3 + a_4 \ln X_4 + a_5 \ln X_5 + a_6 \ln X_6 + a_7 \ln X_7 + a_8 \ln X_8 + e_i$			
Endogenous variable			
Yield (kg/ha)	-	-	-
Exogenous variables			
Human labor	0.37	0.489*	2.05
Machinery	0.18	0.274**	0.28
Diesel fuel	-0.15	-1.388	-0.41
Farmyard manure	0.11	1.253*	1.80
Chemical fertilizers	0.31	0.433*	1.26
Chemicals	0.04	1.075**	0.22
Electricity	0.24	1.176**	1.39
Water for irrigation	0.29	2.507**	0.75
Durbin-Watson	1.57		
R^2 0.98			
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	1.39		

*: Significant at 1% level; **: Significant at 5% level

significance level in the estimated model. The coefficient of determination (R^2) was 0.98 for this model, implying that around 0.98 of the variability in the energy inputs was explained by this model.

As it could be seen in Table 4, the impact of energy inputs could be assessed positive on yield (except diesel fuel). The contribution of human labor, farmyard manure and chemical fertilizer energies are significant at the 1% level (Table 4). This indicates that with an additional use of 1% for each of these inputs would lead, respectively, to 0.37, 0.11 and 0.31% increase in yield. The elasticities of machinery, chemicals, electricity and water energies were estimated as 0.18, 0.04, 0.24 and 0.29, respectively (all significant at the 5% level). Human labor had the highest impact (0.37) among other inputs followed by chemical fertilizers (0.31). Mohammadi and Omid (2010) estimated an econometric model for cucumber production. They concluded that elasticities of human labor, machinery, diesel fuel, farmyard manure, chemicals, water for irrigation and electricity are significant and human labor energy had the highest impact among the other inputs in yield.

The regression coefficients of direct and indirect energies (Model 2) as well as renewable and nonrenewable energies (Model 3) on yield were investigated through Eq. (7) and (8), respectively and results are given in Table 5. As shown, the regression coefficients of direct, indirect, renewable and non-renewable energies were all positive and statistically significant at 1% level. The impacts of direct, indirect, renewable and non-renewable energies were estimated as 0.37, 0.82, 0.41 and 0.75, respectively. It concludes that the impact of indirect energy was more than the impact of direct energy on yield, and the impact of non-renewable energy was more than renewable energy in mandarin production. The research results were consistent with finding reported by other authors (Mohammadi and Omid, 2010; Mobtaker *et al*., 2010; Rafiee *et al*., 2010; Banaeian and Zangeneh, 2011). Durbin-Watson values were calculated as 1.30 and 2.081.22 for Models 2 and 3, indicating that there is no autocorrelation in these models. The corresponding R^2 values for these models were as 0.96 and 0.98, respectively.

The return to scale (sum of the elasticities derived in the form of regression coefficients in the Cobb-Douglas production function) was calculated as 1.39, 1.12 and 1.16 for Models 1, 2 and 3, respectively. This implied that a 1% increase in the total energy inputs utilize would lead in 1.39, 1.12 and 1.16% increase in the mandarin yield for these models. The higher value of return to scale than unity implies increasing return to scale.

The sensitivity of various inputs was computed using the MPP method and partial regression coefficients on output level and the results are showed in Table 4. As can be seen, the major MPP was drown for human labor energy (2.05), followed by farmyard manure energy (1.80). This indicates that an increase of 1 MJ in each input of human labor and farmyard manure energy, would lead to an additional increase in yield by 2.05 and 1.80 kg/ha, respectively. Mobtaker *et al*. (2010) examined the sensitivity of energy inputs on barely productivity. They reported that the MPP estimated for human labor energy was the biggest among inputs of energy.

The MPP of diesel fuel energy was found to be -0.41; a negative value of MPP of inputs implies that additional units of inputs are contributing negatively to production, i.e. less production with more input. Hence, it is better to keep the variable resource in surplus rather than utilizing it as a fixed resource (Singh *et al*., 2004).

The MPP of direct, indirect, renewable and non-renewable energy are shown in the last column of Table 5. The MPP of direct, indirect, renewable and non-renewable energy were found to be 0.38, 0.61, 0.46 and 0.89, respectively. This indicates that with an additional

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

Endogenous variable: yield Exogenous variables	Coefficient	t-ratio	MPP
Model 2: $\ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i$			
Direct energy	0.37	3.094*	0.38
Indirect energy	0.82	5.127*	0.61
Durbin-Watson	1.30		
R^2	0.96		
Return to scale ($\sum_{i=1}^{n} \beta_i$)	1.19		
Model 3: $\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$			
Renewable energy	0.41	4.135*	0.46
Non-renewable energy	0.75	4.852*	0.89
Durbin-Watson	1.22		
R^2	0.98		
Return to scale ($\sum_{i=1}^{n} \gamma_i$)	1.16		

*: Significance at 1% level

use of 1MJ of each of the direct, indirect, renewable and non-renewable energy would lead to an additional increase in yield by 0.38, 0.61, 0.46 and 0.89 kg/ha, respectively.

CONCLUSION

Based on the present study the following conclusions are drawn:

- The average of energy input in mandarin production was to be 77501.17 MJ/ha, mainly due to diesel fuel (24%).
- The energy use efficiency, energy productivity, specific energy and net energy of mandarin production in Mazandaran province were 0.77, 0.41 kg/MJ, 2.46 MJ/kg and -17651.17 MJ/ha, respectively.
- The direct and indirect energy inputs were 58.82 and 41.18% of the total energy input, respectively. Renewable energy sources among the inputs had a share of 34.43% of the total energy input, which was smaller than that of non-renewable resources (65.57).
- The impact of human labor, machinery, farmyard manure, chemical fertilizers, chemicals, electricity, and water for irrigation energy inputs was significantly positive on yield.
- The impacts of direct, indirect and renewable and non-renewable energies on yield were estimated as 0.37, 0.82, 0.41 and 0.75, respectively.
- The MPP estimated for human labor energy was the biggest among inputs of energy followed by farmyard manure and Electricity energy inputs, respectively.

NOMENCLATURE

Y_i	yield level of the ith farmer
X_1	human labor energy
X_2	machinery energy
X_3	diesel fuel energy
X_4	farmyard manure energy
X_5	chemical fertilizers energy
X_6	chemicals energy
X_7	electricity energy
X_8	water for irrigation energy
e_i	error term
α_i	coefficients of the exogenous variables
β_i	coefficients of the exogenous variables
γ_i	coefficients of the exogenous variables
DE	direct energy
IDE	indirect energy
RE	renewable energy
NRE	non-renewable energy
MPP_{xj}	marginal physical productivity of jth input
α_i	regression coefficient of jth input
GM(Y)	geometric mean of yield
$GM(X_j)$	geometric mean of jth input energy

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