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MODELING ENERGY FLOW FOR ORANGE PRODUCTION IN IRAN

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ABSTRACT : The objectives of this study were to determine energy use pattern, to obtain relationship between energy inputs and yield, and to make a sensitivity analysis in orange production in Mazandaran, Iran. The results revealed that total energy input for orange production was 62375.18 MJ ha^{-1}; the indirect energy shared about 41% while the direct energy did 59%. Energy use efficiency, energy productivity, specific energy and net energy were 0.99, 0.52 kg MJ^{-1}, 1.92 MJ kg^{-1} and -625 MJ ha^{-1}, respectively. Econometric estimation results revealed that energy inputs of human labor, machinery, farmyard manure, chemical fertilizers, electricity and water for irrigation contributed significantly to the yield. The impact of human labor energy was found as the most important variable that influences yield followed by chemical fertilizers. The results of sensitivity analysis of the energy inputs showed that the MPP of human labor was the highest. Also, the MPP of chemicals and diesel fuel energies were found negative implying that the use of chemicals and diesel fuel energies are in excess for orange production, causing an environmental risk problem in the region.

Keywords*:* Energy use efficiency, Econometric model, Sensitivity analysis, Orange

Abbreviations*:* DE: Direct Energy; IDE: Indirect Energy; RE: Renewable Energy; NRE: Non-Renewable Energy; MPP: Marginal Physical Product.

INTRODUCTION

It has been realized that crop yields and food supplies are directly linked to energy [2]. The intensive use of technological inputs has been associated with soil erosion, groundwater mining, fertilizer and pesticide pollution, and biodiversity loss. Scientists are seeking appropriate environmental regulations and alternative cropping systems to improve the sustainability of crop production [3]. Effective energy use in agriculture is one condition for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction [11, 19]. The main objective in agricultural production is to increase yield and decrease costs. In this respect, the energy analysis is important. Energy analysis is the numerical comparison of the relationship between input and output of a system in terms of energy units [2]. However, the energy analysis shows the methods to minimize the energy inputs and therefore to increase the energy productivity [13]. Hatirli et al. [10] for greenhouse tomato production, Rafiee et al. [16] for apple production, Mohammadi et al. [13] for kiwifruit production, Ghasemi Mobtaker et al. [6] for barley production, Banaeian and Zangeneh [2] for walnut Production, investigated energy inputs and crop yield relationship to develop and estimate an econometric model. Although many experimental works have been conducted on energy use in agriculture, there is no study on the energy inputs - yield relationship and sensitivity analysis of inputs in orange production.

Citrus especially orange is one of the most important horticultural crops in Iran that annual production and area of it placed Iran between 10 first countries of the world [17]. Based on FAO statistics, about 7.75 million tones of citrus were now consumed worldwide each year. In 2008, Iran produced about 80,000 tones of citrus in 5500 ha [7]. Citrus are the most important horticultural crop in Mazandaran province. Today, about 40% of citrus production in Iran is provided in Mazandaran province [1].

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

MATERIALS AND METHODS

Data were collected from 110 orange orchards in Mazandaran province of Iran using a face to face questionnaire in January 2011. The collected data belonged to the production period of 2010. In addition to the data obtained by surveys, the results of previous studies were also used in this study. The size of sample of each stratification was determined Neyman technique [10]. The size of 110 was considered as sampling size. Sample orchards were randomly selected from the study province.

The inputs used in the production of orange were specified in order to calculate the energy equivalences in the study. Energy equivalents' coefficients were calculated based on previous studies. Inputs in barley production were: human labor, machinery, diesel fuel, chemical fertilizers, farmyard manure, chemicals, water for irrigation, and electricity. Energy equivalents showed in Table 1 were used for estimation.

The amounts of input were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. Based on the energy equivalents (Table1), the energy use efficiency (energy ratio), the energy productivity, the net energy gain and the specific energy were calculated as [15]:

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

$$\text{Energy productivity} = \frac{\text{Orange output (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (2)$$

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

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}) - \text{Energy input (MJ ha}^{-1}) \quad (4)$$

Energy use in agriculture can be divided into direct and indirect, renewable and non-renewable energies. Indirect energy included energy embodied in fertilizers, farmyard manure, chemical and machinery while direct energy covered human labor, electricity, diesel fuel, and water for irrigation used in the citrus production process. Non-renewable energy consists of diesel, chemicals, electricity, fertilizers and machinery energies and renewable energy includes human labor, farmyard manure and water for irrigation energies [14, 20].

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 [2, 6, 10, 13, 16]. The Cobb–Douglas production function is expressed as follows [8]:

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

This function can be linearized and further expressed as:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \qquad i = 1,2, \ldots, n \quad (6)$$

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

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Reference
A. Inputs			
1. Human labor	h	1.96	[15]
2. Machinery	h	62.70	[15]
3. Diesel fuel	l	56.31	[13]
4. Chemical fertilizers	kg		
a) Nitrogen (N)		66.14	[13]
b) Phosphate (P_2O_5)		12.44	[13]
c) Potassium (K_2O)		11.15	[13]
5. Farmyard manure	kg	0.30	[13]
6. Chemicals	kg	120	[13]
7. Electricity	kWh	11.93	[15]
8. Water for irrigation	m^3	1.02	[13]
B. Outputs			
1. Orange	kg	1.90	[15]

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, a_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 [10, 13, 16]. Therefore Eq. (6) reduces to:

$$\ln \mathrm{Y_i} = \sum_{j=1}^{n} a_j \ln(\mathrm{X_{ij}}) + e_i \quad (7)$$

in this study Eq. (7) expressed in the flowing form:

$$\ln Y_i = a_1 \ln X_1 + a_2 \ln X_2 + a_3 \ln X_3 + a_4 \ln X_4 + a_5 \ln X_5 + a_6 \ln X_6 + a_7 \ln X_7 + a_8 \ln X_8 + e_i \quad (8)$$

Where; X_i (i = 1, 2 ,…, 8) 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). 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:

$$\ln Y_i = \beta_0 + \beta_1 \ln DE + \beta_2 \ln IDE + e_i \quad (9)$$

$$\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \quad (10)$$

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. (8)-(10) 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 orange yield and returns to scale of Cobb–Douglas function was calculated. The MPP 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 calculated using the α_j of the various energy inputs as follow [18]:

$$MPP_{xj} = \frac{GM\,(Y)}{GM\,(X_j)} \times \alpha_j \qquad (11)$$

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.

A positive value of MPP of any input variable identifies 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 indicates that every 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 [2].

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 [18].

Basic information on energy inputs and orange output were entered into Excel 2007 spreadsheet and SPSS 16.0 software for simulating.

RESULTS AND DISCUSSION

Analysis of input–output energy use in orange production

The inputs used in orange production and their energy equivalents with output energy rates are shown in the Table 2. The last column in Table 2 gives the percentage of each input of the total energy input. As it can be seen in the Table 2, about 94 kg nitrogen, 343 kg phosphate, 218 kg potassium, 16 tons of farm yard manure, 300 l diesel fuel, 12570 m^3 water, 16.30 kg chemical spraying agents, 1100 h human labor, 60 h machinery, 425 kWh electrical energy per hectare are used for the orange production. The total energy input for various processes in the orange production was calculated to be 62375.18 MJ ha^{-1} (Table 2). Table 2 shows the highest energy input is provided by diesel fuel followed by chemical fertilizer. Ozkan et al. [15] for orange, mandarin and lemon productions, Yilmaz et al. [20] for cotton, and Esengun et al. [5] for stake-tomato reported that the highest energy input is provided by diesel fuel followed by fertilizers. From Table 2 it is shown that human labor was the least demanding energy input for orange production with 2156 MJ ha^{-1} (only 3% of the total sequestered energy), followed by chemicals by 3271.75 MJ ha^{-1}(5%). The mean yield and energy output of orange production was 32.5 tons and 61750 MJ ha^{-1}, respectively (Table 2).

The energy use efficiency, the energy productivity, the net energy gain and the specific energy of orange production in the Mazandaran Province are calculated using Eqs. (1)-(4) and tabulated in Table 3. The energy use efficiency (energy ratio) in the orange production was found as 0.99 (Table 3).

Table 2- Amounts of inputs and output in orange production

Inputs (unit)	Quantity per unit area (ha)	Total energy Equivalent (MJ ha^{-1})	%
A. Inputs			
1.Human labor (h)	1100.00	2156.00	3.46
2.Machinery (h)	60.00	3762.00	6.03
3.Diesel fuel (l)	300.00	16893.00	27.08
4.Chemical fertilizer (kg)		13600.78	21.81
a) Nitrogen	94.00	6217.16	9.97
b) Phosphate	343.00	4952.92	7.94
c) Potassium	218.00	2430.70	3.90
5.Farm yard manure (kg)	16000.00	4800.00	7.69
Chemicals (kg)		3271.75	5.24
a) Pesticides	4.35	865.65	1.39
b) Fungicides	3.00	276.00	0.44
c) Herbicides	8.95	2130.10	3.41
6.Electricity (kWh)	425.00	5070.25	8.13
7.Water for irrigation (m^3)	12570.00	12821.40	20.56
Total energy input (MJ)	-	62375.18	100
B. Output			
1.Orange (kg)	32500.00	61750.00	

In previous investigations, Ozkan at al. [15] in Turkey calculated energy ratio as 1.25 for orange production. The average energy productivity of orange orchards was 0.52kg MJ^{-1}. This means that in orange production 0.52 kg output was obtained per unit energy (MJ) in Mazandaran province. Specific energy in orange production was calculated as 1.92 MJ kg^{-1}. Other researchers reported similar values for specific energy such as 5.24 for wheat, 3.88 for maize, 1.14 for tomato in Turkey [4] and 3.97 and 4.72 for potato in Iran [21]. The net energy in orange production was -625.18 MJha^{-1}. Therefore, it is concluded that in orange production in Mazandaran province, energy has been lost. Similarly, Zangeneh et al. [21] for potato, Mohammadi and Omid [12] for greenhouse cucumber, reported negative value for net energy. Based on the structure of farming system and the level of technology in orange orchards of Mazandaran province, the less than zero value for the net energy is reasonable.

Table 3- Some energy parameters in orange production in Mazandaran province of Iran.

Items	Unit	orange	Share (%)
Energy use efficiency	-	0.99	-
Energy productivity	kg MJ^{-1}	0.52	-
Specific energy	MJ kg^{-1}	1.92	-
Net energy	MJ ha^{-1}	-625.18	-
Direct energy [a]	MJ ha^{-1}	36940.65	59.22
Indirect energy [b]	MJ ha^{-1}	25434.53	40.78
Renewable energy [c]	MJha^{-1}	19777.4	31.71
Non-renewable energy [d]	MJ ha^{-1}	42597.78	68.29
Total energy input [e]	MJ ha^{-1}	62375.18	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.

Also the distribution of inputs used in the production of orange according to the direct, indirect, renewable and non-renewable energy groups, are given in Table 3. About 40.8% of the total energy inputs used in orange production was indirect while about 59.2% was direct. Approximately 68.3% of total energy input from non-renewable and only 31.7% from renewable energy forms. Ozkan et al. [15] reported direct, indirect, renewable and non-renewable energies as 50.52, 49.13, 3.90 and 95.75%, respectively in orange production in Turkey.

Econometric model estimation of energy inputs for orange production

Orange yield (endogenous variable) was assumed to be a function of human labor, machinery, diesel fuel, farmyard manure, chemical fertilizers, chemicals, electricity and water for irrigation energy (exogenous variables). For estimating the relationship between energy inputs and yield the Cobb–Douglas function was used. The values of coefficients α_i, β_i and γ_i appearing in Eqs. (9-11) were calculated for the orange production (Table 4). The corresponding R^2 values were also determined. Autocorrelation for Eqs (9- 11) have tested with Durbin–Watson test [9]. This test revealed that Durbin-Watson value was as 1.62 for Eq.9, i.e., there was no autocorrelation at the 5% significance level in the estimated model. For this model value of R^2 was 0.98 (Table 4). Regression result for Eq. 9 is shown in Table 4. The impact of energy inputs on yield was also investigated by estimating Eq. (9). As shown in this Table, the contribution of human labor, farmyard manure, chemical fertilizers and machinery energies are significant at the 1% level of confidence. This shows that with an additional use of 1% for each of these inputs would lead, respectively, to 0.45, 0.14, 0.39 and 0.04% increase in yield. Table 4 shows the contribution of electricity and water for irrigation energies are significant at the 5% level of confidence. Similar results were observed by other researches [6, 10]. Among the variables included in the model, chemical fertilizers energy was found as the most important variable that influences yield with 0.39 of elasticity. The second important input was found as water for irrigation with 0.33 elasticity followed by electricity with 0.28 elasticity. Hatrili et al. [10] concluded that in greenhouse tomato production of Turkey, the impact of chemical fertilizers energy was the most important variable that influences yield.

Estimated coefficients indicate that elasticity for diesel fuel and chemicals are negative with -0.12 and -0.07 respectively. Banaeian and Zangeneh [2] reported that in walnut production the impact of chemical fertilizers, machinery and diesel fuel energies on yield had negative influence.

Regression coefficients of direct and indirect energies (Model 2) also renewable and non-renewable energies (Model 3) on yield were investigated and results are shown in Table 5. As shown, the regression coefficients of direct, indirect, renewable and non-renewable energies were all statistically significant at 1% level. The impacts of direct, indirect, renewable and non-renewable energies were estimated as 0.48, 0.74, 0.34 and 0.81, respectively. Durbin–Watson values were calculated as 1.78 and 1.17 for Eqs. (9), (10), respectively (Table 5). R^2 values for these models were as 0.98 and 0.97, respectively (Table 5). Similarly other studies reported 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 [6, 9, 10, 16].

The sum of the regression coefficients of energy inputs (return to scale) was calculated as 1.44, 1.22 and 1.15 for Eqs. 8, 9 and 10, respectively. This implied that a 1% increase in the total energy inputs utilize would lead in 1.44%, 1.22% and 1.15% increase in the orange yield for these Eqs. Thus, there prevailed an increasing return to scale for estimated models.

Sensitivity analysis of various energy inputs on the production of orange

The sensitivity of energy inputs was analyzed using the MPP method and the results are showed in table 4. As can be seen the major MPP was drown for human labor energy (2.17). This reveals that additional utilize of 1MJ for human labor energy would result in an increase in yield by 2.17 kg. Similarly Ghasemi Mobtaker et al. [6] and Banaeian and Zangeneh [2] reported the MPP of human labor was high.

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 labour	0.45	0.237*	2.17
Machinery	0.04	1.661*	0.07
Diesel fuel	-0.12	-0.623	-0.28
Farmyard manure	0.14	2.473*	1.36
Chemical fertilizers	0.39	0.683*	0.51
Chemicals	-0.07	-1.465	-0.96
Electricity	0.28	1.742**	1.16
Water for irrigation	0.33	1.341**	0.44
Durbin-Watson	1.62		
R^2	0.98		
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	1.44		

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

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	0.48	2.407*	0.48
Indirect energy	0.74	6.275*	0.56
Durbin-Watson	1.78		
R^2	0.98		
Return to scale ($\sum_{i=1}^{n} \beta_i$)	1.22		
Model 3: $\ln Y_i = \gamma_0 + \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i$			
Renewable energy	0.34	5.117*	0.34
Non-renewable energy	0.81	4.982*	0.92
Durbin-Watson	1.15		
R^2	0.97		
Return to scale ($\sum_{i=1}^{n} \gamma_i$)	1.15		

*: Significance at 1% level.

The MPP of the machinery, farmyard manure, chemical fertilizers, electricity and water for irrigation were determined as 0.07, 1.36, 0.51, 1.16 and 0.44, respectively. This indicates that additional utilize of 1MJ for each of these input energies would result in an increase in yield by 0.07, 1.36, 0.51, 1.16 and 0.44 kg, respectively. Hence, exogenous parameters with large sensitivity coefficients have a strong impact on the endogenous variable [6]. The MPP of diesel fuel, and chemicals were negative (-0.28 and -0.96). This means that additional units of these inputs are contributing negatively to production i.e. less production with more input. Ghasemi mobtaker et al. [6] reported that MPP of chemicals in barley production was negative.

The sensitivity analysis of energy inputs as direct, indirect, renewable and non-renewable forms are showed in table 5. The MPP of these forms were found to be 0.48, 0.56, 0.34 and 0.92, respectively. This indicates that with an additional use of 1MJ of each of the direct, indirect, renewable and non-renewable energy would lead to an additional increase in yield by 0.48, 0.56, 0.34 and 0.92 kg, respectively.

Conclusion

Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system. The aim of this study was to analyze sensitivity of a particular energy input level on orange yield in Mazandaran Province, Iran. Based on the results of the investigations, the following conclusions were drawn:

1) The average of energy input in orange production was to be 62375.18 MJ ha^{-1}. The energy input of diesel fuel has the biggest share within the total energy inputs followed by chemical fertilizer. Approximately 68.29% of total energy input from non-renewable and only 31.71% from renewable energy forms.

2) Regression result between energy inputs and yield showed that contribution of human labor, machinery, farm yard manure, chemical fertilizers, electricity and water for irrigation are significant on output level. The impact of human labor energy was found as the most important variable that influences yield with 0.45 of elasticity.

3) MPP of chemicals energy and diesel fuel were found negative, indicating that chemicals and diesel fuel energies consumption is high in orange production.

4) Energy management is an important issue in terms of efficient, sustainable and economic use of energy.

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