INTERNATIONAL JOURNAL OF
ENERGY AND ENVIRONMENT

Volume 2, Issue 5, 2011 pp.845-852
Journal homepage: www.IJEE.IEEFoundation.org

Energy efficiency and cost analysis of canola production in different farm sizes

S. H. Mousavi-Avval, S. Rafiee, A. Jafari, A. Mohammadi

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

Abstract
Efficient use of energy in agriculture is one of the conditions for sustainable agricultural production. The aims of this study were to determine the amount of input–output energy used in canola production, to investigate the efficiency of energy consumption and to make an economic analysis of canola production in different farm sizes. Data used in this study were obtained from 130 randomly selected farms in Golestan province, the most important centre of oilseed production in Iran. The surveyed farms were classified into three groups of small (less than 2 ha), medium (2 to 4 ha) and large farms (more than 4 ha). The results revealed that total energy input for canola production increased from 15817.24 MJ ha^{-1}, in small farms, to 20663.13 MJ ha^{-1}, in large farms; while, the highest yield value (2286.36 kg ha^{-1}) was obtained from medium farms. The results also revealed that the medium farms had the highest energy use efficiency (3.75) and benefit to cost ratio (1.59); indicating a better management of energy and input consumptions in these farms. Moreover, the energy use efficiency for small and large farms was found to be 3.35 and 3.07, respectively.

Keywords: Energy efficiency; Energy management; Profitability; Farm size; Canola productiont

1. Introduction
Canola (*Brassica napus L.*) is one of the leading annual oilseed crops cultivated for production of oil mainly used for human consumption. Canola production in Iran has increased dramatically in recent years, increasing from 76,430 tones in 2003, to more than 390,000 tones in 2008 [1]. Canola production and its supply chain are heavily dependent on inputs such as land, water, fertilizer, fuel, machines, pesticides and electricity. The expansion of this crop in Iran has generated concerns about its environmental impacts.
Energy is an integral part of a society and plays a pivotal role in its economic growth and social development by raising the standard of living and the quality of life [2]. Scientific forecasts and analysis of energy consumption will be of great importance for the planning of energy strategies and policies [3]. The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy [4]. Energy consumption in developing countries has been increasing rapidly due to recent economic growth and development [5]; however, increased input use in agricultural production may not bring maximum profits due to increasing production costs [6]. Furthermore, intensive use of energy causes problems threatening public health and the environment. Efficient use of energy is one of the principal requirements for sustainable agricultural productions [7]. It will minimize environmental problems and improve sustainable agriculture as an economical production system [8].

The development of agricultural systems with low input of energy compared to the output of food would result in improvement of energy use efficiency and reduction of the environmental impacts [9].
Improving the energy efficiency not only helps in improving competitiveness through cost reduction but also results in minimized energy-related environmental pollution, thus positively contributing towards sustainable development [10]. The energy input-output analysis is usually made to evaluate the efficiency and environmental impacts of production systems. This analysis will determine how efficient the energy is used. In recent years, many researchers have investigated the energy use for agricultural productions [11, 12]. Moreover, in some studies the effect of farm size on energy use efficiency of agricultural production was investigated; Esengun et al. [13] examined the dry apricot production in different farm sizes in terms of energy use efficiency and economical analysis. They reported that, both the total energy input and output energy in apricot production decreased when farm size increased; while, the energy use efficiency and energy productivity increased when farm size increased. Yilmaz et al. [14] investigated the effect of farm size on energy use and input costs for cotton production in Turkey; from this study it was found that large farms were more successful in energy productivity, use efficiency and economic performance; also, it was concluded that energy management at farm level could be improved to give more efficient and economic use of energy. Cetin and Vardar [15] investigated the energy consumption in small, medium and large farms of tomato production; they concluded that large farms were more successful in terms of energy use and economic performance.
Based on the literature, there was no study on energy and economical analysis of canola productions in Iran. Therefore, the main objective of this study was to compare the energy use and economic efficiencies of canola production in different farm sizes in Golestan province of Iran.

2. Materials and methods

The investigation was conducted on canola farms in Golestan province, Iran. Golestan province is the most important centre of canola production in Iran. The province is located within 36° 30' and 38° 08' north latitude and 53° 57' and 56° 22' east longitude, in the north-east of Iran. Data on canola production were collected from the canola farms by using a survey method. The collected information belonged to the 2009-2010 production period. The sample size was determined using the random sampling method [8]; so, it was calculated as 130 and then the 130 farms were randomly chosen from 30 villages in the area of study. For the analysis of energy use in different farm sizes, the selected farms were classified into three groups of less than 2 ha, 2 to 4 ha and more than 4 ha.
For calculating the energy equivalents, firstly, the amount of inputs used in the production of canola (i. e., chemicals, human labour, machinery, seed, farmyard manure, fertilizers, fuel, electricity and irrigation water) were specified. Consequently, the energy equivalents were computed for all inputs and outputs using the conversion factors for machinery and diesel fuel [16], human labour [17], chemical fertilizers, FYM and water for irrigation [8], chemicals [6], canola seed and output [18] and electricity [19]. Multiplying the physical quantities of inputs with their energy conversion factors gave the energy equivalents reported in MJ per hectare unit.
The energetic efficiency of the agricultural systems can be evaluated by the relation between energy inputs and output [20]. Based on the energy equivalents of inputs and outputs, the indices of energy use efficiency, energy productivity, specific energy and net energy were calculated using the following Eqs [8]:

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

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

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

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

Energy use efficiency is defined as the ratio between the caloric heat of the output products and the total sequestered energy in the production factors. Energy productivity is the amount of a product obtained per unit of input energy. Energy output and net energy are crucial parameters when the availability of arable land is the limiting factor for plant production [21].
The energy inputs were divided into direct and indirect and renewable and non-renewable energy forms [18]. Direct energy consisted of human labour, diesel fuel and electricity; whereas, indirect energy included machinery, chemical fertilizers, farmyard manure, biocides and seeds. On the other hand, renewable energy consists of human labour, farmyard manure and seeds and non-renewable energy includes machinery, diesel fuel, chemical fertilizers, biocides and electricity.

In the last part of this study the economic analysis of canola production in different farm sizes was investigated. So the following indicators were used [22, 23]:

Total production value = Canola yield (kg ha^{-1}) × Canola price ($ kg^{-1}) (5)
Gross return = Total production value ($ ha^{-1}) – Variable cost of production ($ ha^{-1}) (6)
Net return = Total production value ($ ha^{-1}) – Total production costs ($ ha^{-1}) (7)
Benefit - Cost ratio = Total production value ($ ha^{-1}) / Total production costs ($ ha^{-1}) (8)
Productivity = Canola yield (kg ha^{-1}) / Total production costs ($ ha^{-1}) (9)

All estimations were carried out using the Microsoft Excel spreadsheet and SPSS 17.0 software programs.

3. Results and discussion

3.1 Analysis of input-output energy use in canola production

The amount of inputs and outputs for canola production in different farm sizes are presented in Table 1. The results revealed that, the human labour was required as 90.77, 76.63 and 69.8 h ha^{-1}, in small, medium and large farms, respectively. Also, in the respective farms 13.57, 13.96 and 14.05 h per hectare of machine power were consumed. The chemical fertilizer usage in medium farms was found to be 175.55 kg ha^{-1}; also, it decreased while farm size increased. On the other hand, the canola yield for small farms was calculated as 1900.92 kg ha^{-1}. However, in medium and large farms it was found to be significantly higher as 2286.36 and 2249.2 kg ha^{-1}, respectively.

Table 1. Amounts of inputs and output in different farm sizes of canola production in Golestan, Iran

Item	Small farms	Medium farms	Large farms
A. Inputs			
1. Human labour (h)	90.77	76.63	69.8
2. Machinery (h)	13.57	13.96	14.05
3. Diesel fuel (L)	98.68	104.52	101.06
4. Chemicals (kg)	2.29	2.79	2.66
a. Herbicides	1.23	1.38	1.22
b. Fungicides	0.72	0.98	0.93
c. Insecticides	0.34	0.43	0.51
5. Chemical fertilizer (kg)	163.89	175.54	219.13
a. Nitrogen	95.58	102.83	134.23
b. Phosphate (P_2O_5)	51.72	48.69	51.59
c. Potassium (K_2O)	11.49	14.28	14.26
d. Sulfur (S)	5.11	9.73	19.04
6. FYM	1721.25	1602.27	1556.3
7. Water for irrigation (m^3)	99.57	171.75	459.59
8. Electricity (kWh)	145.36	137.38	296.62
9. Seed (kg)	8.22	8.06	8.38
B. Output			
1. Canola yield (kg)	1900.92[a]	2286.36[b]	2249.2[b]

The energy equivalents of inputs and output are presented in Table 2. The results revealed that, total energy input in small and medium farms was 15811.85 and 16674.73 MJ ha^{-1}, respectively; however, in large farms, it was found to be significantly higher as 20670.89 MJ ha^{-1}. The energy equivalent of chemical fertilizer input in small and medium farms was nearly the same; while, fertilizer usage in large farms was considerably higher. It was mainly due to the high use of nitrogen fertilizer in these farms. Also, electrical energy consumption in large farms was the highest (3538.68 MJ ha^{-1}); while it was found to be 1734.09 and 1638.96 MJ ha^{-1} in small and medium farms, respectively. The total output energy in small, medium and large farms was found to be 47523.05, 57159.09 and 56230.09 MJ ha^{-1}, respectively.

Table 2. Energy inputs and output in different farm sizes of canola production in Golestan, Iran

Item	Small farms	Medium farms	Large farms
A. Inputs (MJ ha^{-1})			
1. Human labour	177.92	150.2	136.8
2. Machinery	953.9	1044.76	955.68
a. Tractor	332.48	335.07	348.62
b. Self propelled combine	453.9	533.25	430.48
c. Other machinery	167.52	176.45	176.58
3. Diesel fuel	4716.67	4996	4830.66
4. Chemicals	483.12	582.84	542.89
a. Herbicides	293.15	327.56	289.57
b. Fungicides	155.41	211.58	201.6
c. Insecticides	34.56	43.7	51.72
5. Chemical fertilizer	7098.64	7577.18	9700.34
a. Nitrogen	6321.45	6801.32	8878.16
b. Phosphate	643.37	605.7	641.81
c. Potassium	128.09	159.27	159.03
d. Sulfur	5.72	10.9	21.32
6. FYM	516.38	480.68	466.89
7. Water for irrigation	101.56	175.18	468.78
8. Electricity	1734.09	1638.96	3538.68
9. Seed	29.58	29	30.16
Total energy input	15811.85[a]	16674.73[a]	20670.89[b]
B. Output (MJ ha^{-1})			
Total energy output	47523.05[a]	57159.09[b]	56230.09[b]

(a, b) are significant different (P<0.05)

The percentage associated of energy inputs in different farm sizes of canola production are depicted in Figure 1. As it is seen, in all the three groups of farm sizes the chemical fertilizer, diesel fuel and electricity were the main energy consuming inputs, respectively. Moreover, the contributions of human labour, machinery and seed energies from total energy input were found to be relatively low.

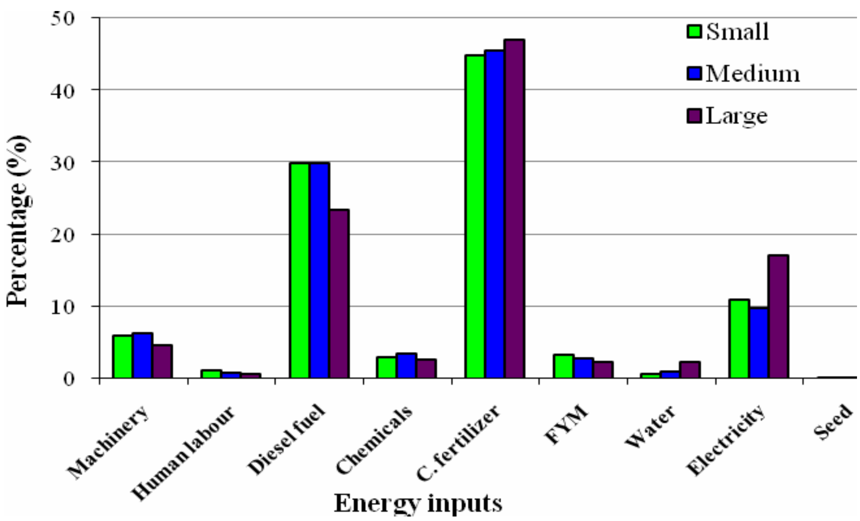

Figure 1. Distribution of energy inputs in different farm sizes of canola production

Similar studies had also reported that fertilizer and diesel fuel were the most intensive energy inputs [6,19,24,25]; Kallivroussis et al. [26] reported that the main energy consuming inputs for sunflower production in Greece were nitrogen fertilizer (42.4%) and diesel fuel (33.9%). Excessive use of chemical fertilizers energy input in agriculture may create serious environmental consequences such as nitrogen loading in the environment and receiving waters, poor water quality, carbon emissions and contamination of the food chain [27]. Integrating a legume into a crop rotation is energetically favourable to reduce the nitrogen fertilizer requirement. Also, application of composts, chopped residues or other soil amendments may increases soil organic matter content and fertility in the medium term and so reduces the need for chemical fertilizer energy input [28]. Moreover, applying a better machinery management technique, employing the conservation tillage methods or technological upgrade to substitute fossil fuels with renewable energy sources may be the pathways to minimize the fossil fuel usage and thus to reduce its environmental impacts.

The energy indicators for canola production in three farm sizes are tabulated in Table 3. The results revealed that, canola production in medium farms showed the highest energy use efficiency as 3.43, while, energy use efficiency in large farms was the lowest as 3.01; moreover, it had not significant difference in small farms compared with medium and large farms. These results were possible because canola yields and consequently energy output were highest in medium farms; also, these farms had the lowest total energy input. The energy productivity in small, medium and large farms was found to be 0.12, 0.14 and 0.11 kg MJ^{-1}, respectively. Also, specific energy in medium farms was the lowest (7.29 MJ kg^{-1}) and it was highest in large farms (9.19 MJ kg^{-1}). Moreover the medium farms had the highest net energy.

Table 3. Some energy indices in different farm sizes of canola production in Golestan, Iran

Item	Unit	Small farms	Medium farms	Large farms
Energy use efficiency	-	3.01^{ab}	3.43^{a}	2.72^{b}
Energy productivity	kg MJ^{-1}	0.12	0.14	0.11
Specific energy	MJ kg^{-1}	8.32	7.29	9.19
Net energy	MJ ha^{-1}	31711.2	40484.36	35559.2
Direct energy	MJ ha^{-1}	6730.25	6960.26	8974.93
Indirect energy	MJ ha^{-1}	9081.61	9714.47	11695.96
Renewable energy	MJ ha^{-1}	2457.96	2298.85	4172.53
Non-renewable energy	MJ ha^{-1}	13353.89	14375.89	16498.36
Total energy input	MJ ha^{-1}	15811.85^{a}	16674.73^{a}	20670.89^{b}

(a, b) are significant different ($P<0.05$)

The distribution of inputs used in the production of canola according to the direct, indirect, renewable and non-renewable energy forms for all of farm groups are also given in Table 3. The results revealed that, in all of the farm groups, the rate of direct energy was greater than that of indirect energy and the contribution of non-renewable energy forms was higher than that of renewable energy consumption. Moreover, the ratio of direct and indirect energy resources were nearly the same, while, the rates of renewable and non-renewable energies were fairly different from each other.

3.2 *Economical analysis of canola production in different farm sizes*

In Table 4 the economical analysis of canola production in three groups of farms are comparatively presented. The total production values, gross and net returns and benefit to cost ratio were calculated using Eqs (5) - (9). The fixed and variable expenditures included in the cost of production were calculated in detail. The variable cost of production for small, medium and large farms was found to be 403.52, 371.02 and 358.49 \$ ha^{-1}, respectively. The higher variable expenditure in small farms was mainly due to higher costs of human labour and machinery in these farms. As mentioned above, the machinery usage in small and large farms was found to be the lowest and highest, respectively; however, the high cost of machinery in small farms was due to the fact that machinery employment in small farms was mainly rental; while, in large farms it was mainly owned, resulted in highest fixed cost in large farms and lowest fixed cost in small farms (Table 4).

The total cost of production in medium farms was found to be as low as 907.6 \$ ha^{-1}. Also, in small and large farms it was found to be 930 \$ ha^{-1}. On the other hand, the fixed costs of production in small, medium and large farms was found to be 526.55, 536.57 and 571.19 \$ ha^{-1}, respectively. The net return for canola production in small, medium and large farms was calculated as 267.51, 532.81 and 487.31 \$ ha^{-1}, respectively. Also, medium and small farms had the highest and lowest benefit to cost ratio, respectively, (1.59 vs. 1.29); also, it was found to be 1.52 for medium farms. These results were possible because medium farms had the highest yield and also the lowest expenditure; moreover, small farms had the lowest production yield and the highest production costs.

Table 4. Economical analysis of canola production in different farm sizes in Golestan, Iran

Item (Unit)	Small farms	Medium farms	Large farms
Yield (kg ha^{-1})	1900.92	2286.36	2249.2
Sale price ($ kg^{-1})	0.63	0.63	0.63
Total production value ($ ha^{-1})	1197.58	1440.41	1417
Variable cost of production ($ ha^{-1})	403.52	371.02	358.49
Human labour	99.23	89.11	81.96
Chemicals	35.82	42.46	39.6
Chemical fertilizer	39.6	42.6	60.65
Farmyard manure	13.9	11.54	9.98
Seed	33.3	29.09	33.99
Machinery	145	122.5	99.72
Various costs	36.68	33.73	32.59
Fixed cost of production ($ ha^{-1})	526.55	536.57	571.19
Depreciation	20.45	32.59	39.53
Land and water	506.1	503.98	531.67
Total cost of production ($ ha^{-1})	930.07	907.6	929.69
Total cost of production ($ kg^{-1})	0.49	0.4	0.41
Gross return ($ ha^{-1})	671.03	903.84	845.8
Net return ($ ha^{-1})	267.51	532.81	487.31
Benefit to cost ratio	1.29	1.59	1.52
Productivity ($ kg^{-1})	2.04	2.52	2.42

4. Conclusions

In this study the energy use efficiency and benefit to cost ratio of canola production in small, medium and large farms was examined. Data used in this study were obtained from 130 randomly selected canola farms in Golestan province, Iran. The results revealed that, total energy input in large farms was significantly higher than that of small and medium farms; also, the yield value of canola in small farms was significantly lower than that of medium and large farms. Consequently, the energy use efficiency and energy productivity were found to be the highest in medium farms. Also medium farms had the highest benefit to cost ratio.

Energy management should be considered as an important issue in terms of sustainable, efficient and economic use of energy. Energy use in small and large farms of canola production is not efficient and detrimental to the environment mainly due to excessive use of intensive energy inputs. Integrating a legume into the crop rotation, application of composts, chopped residues or other soil amendments and also employing the conservation tillage methods would be useful not only for providing higher energy use efficiency and decreasing production costs, but also for reducing negative effects to the environment, human health and for maintaining sustainability.

References

[1] Anonymous, Food and Agricultural Organization (FAO). www.fao.org, 2010.

[2] Singh S., Bajpai, U. Integrated energy planning for sustainable development in rural areas: A case study from Eastern Uttar Pradesh. Int. J. Energy Environ. 2010, 1(6), 1083-1096.

[3] Liang Q.M., Fan Y., Wei Y.M. Multi-regional input-output model for regional energy requirements and CO2 emissions in China. Energy Policy 2007, 35(3), 1685-1700.

[4] Mohammadi A., Tabatabaeefar A., Shahin S., Rafiee S., Keyhani A. Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Convers. Manage. 2008, 49(12), 3566-3570.

[5] Iwaro J., Mwasha A. Implications of building energy standard for sustainable energy efficient design in buildings. Int. J. Energy Environ. 2010, 1(5), 745-756.

[6] Erdal G., Esengün K., Erdal H., Gündüz O. Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy 2007, 32(1), 35-41.

[7] Schroll H. Energy-flow and ecological sustainability in Danish agriculture. Agric. Ecosyst. Environ. 1994, 51(3), 301-310.

[8] Rafiee S., Mousavi Avval S.H., Mohammadi A. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy 2010, 35(8), 3301-3306.

[9] Dalgaard T., Halberg N., Porter J.R. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. Agric. Ecosyst. Environ. 2001, 87(1), 51-65.

[10] Nagesha N. Role of energy efficiency in sustainable development of small-scale industry clusters: an empirical study. Energy Sustain. Develop. 2008, 12(3), 34-39.

[11] Moore S.R. Energy efficiency in small-scale biointensive organic onion production in Pennsylvania, USA. Renew. Agric. Food Syst. 2010, 25, 181-188.

[12] 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(1), 35-43.

[13] Esengun K., Gunduz O., Erdal G. Input-output energy analysis in dry apricot production of Turkey. Energy Convers. Manage. 2007, 48(2), 592-598.

[14] Yilmaz I., Akcaoz H., Ozkan B. An analysis of energy use and input costs for cotton production in Turkey. Renew. Energy 2005, 30(2), 145-155.

[15] Çetin B., Vardar A. An economic analysis of energy requirements and input costs for tomato production in Turkey. Renew. Energy 2008, 33(3), 428-433.

[16] Canakci M., Topakci M., Akinci I., Ozmerzi A. Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. Energy Convers. Manage. 2005, 46(4), 655-666.

[17] Gundogmus E. Energy use on organic farming: A comparative analysis on organic versus conventional apricot production on small holdings in Turkey. Energy Convers. Manage. 2006, 47(18-19), 3351-3359.

[18] Beheshti Tabar I., Keyhani A., Rafiee S. Energy balance in Iran's agronomy (1990-2006). Renew. Sust. Energy Rev. 2010, 14(2), 849-855.

[19] Mobtaker H.G., 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), 367-372.

[20] Ghorbani R., Mondani F., Amirmoradi S., Feizi H., Khorramdel S., Teimouri M., Sanjani S., Anvarkhah S., Aghel H. A case study of energy use and economical analysis of irrigated and dryland wheat production systems. Appl. Energy 2011, 88(1), 283-288.

[21] Tabatabaeefar A., Emamzadeh H., Varnamkhasti M.G., Rahimizadeh R., Karimi M. Comparison of energy of tillage systems in wheat production. Energy 2009, 34(1), 41-45.

[22] Demircan V., Ekinci K., Keener H.M., Akbolat D., Ekinci C. Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. Energy Convers. Manage. 2006, 47(13-14), 1761-1769.

[23] Zangeneh M., Omid M., Akram A. A comparative study on energy use and cost analysis of potato production under different farming technologies in Hamadan province of Iran. Energy 2010, 35(7), 2927-2933.

[24] Kizilaslan H. Input-output energy analysis of cherries production in Tokat Province of Turkey. Appl. Energy 2009, 86(7-8), 1354-1358.

[25] Mousavi Avval S.H., Rafiee S., Jafari A., Mohammadi A. Energy Use Pattern Analysis of Sunflower Production in Golestan Province of Iran. In Proceedings of International Agricultural Engineering Conference 2010. Sept. 16-20, Shanghai, China 2010, 369-375.

[26] Kallivroussis L., Natsis A., Papadakis G. The energy balance of sunflower production for biodiesel in Greece. Biosyst. Eng. 2002, 81(3), 347-354.

[27] Khan S., Khan M.A., Hanjra M.A., Mu J. Pathways to reduce the environmental footprints of water and energy inputs in food production. Food Policy 2009, 34(2), 141-149.

[28] Metzidakis I., Martinez-Vilela A., Castro Nieto G., Basso B. Intensive olive orchards on sloping land: Good water and pest management are essential. J. Environ. Manage. 2008, 89(2), 120-128.

S. H. Mousavi-Avval was born in 1987 in Khorasan/Iran, received his B.Sc. degree in Agricultural Mechanization Engineering from the University of Tehran, Iran, in 2009. He is now M.Sc. student in Agricultural Mechanization Engineering in University of Tehran under supervision of Dr. Shahin Rafiee. His main research interests are agricultural mechanization and energy in agriculture.
E-mail address: sh.mousavi@ut.ac.ir

S. Rafiee was born in 1974 in Tehran/Iran, received his B.Sc. and M.Sc. degrees in Agricultural Machinery Engineering from the University of Tehran, Iran, in 1993 and 1999, respectively. He received his Ph.D. degree in Agricultural Machinery Engineering from Tarbiat Modares University, Iran. He is currently an Associate Professor in Department of Agricultural Machinery Engineering in University of Tehran. His current research interests are energy, modeling and simulation, and mechanization.
E-mail address: shahinrafiee@ut.ac.ir

A. Jafari was born in 1970, received his B.Sc. degree in Agricultural Machinery Engineering from the University of Tehran, Iran, in 1993. He received his M.Sc. and Ph.D. degrees in Mechanics of Agricultural Machinery Engineering from Tarbiat Modares University, Iran, in 1996 and 2002, respectively. He is currently an Associate Professor in Department of Agricultural Machinery Engineering in University of Tehran. His current research interest is mechanics of agricultural machinery.
E-mail address: jafarya@ut.ac.ir

A. Mohammadi was born in 1983 in Tehran/Iran, received his B.Sc. and M.Sc. degrees in Agricultural Machinery Engineering from the Urumia University and University of Tehran, Iran, in 2005 and 2008, respectively. He is now Ph.D. student in Agricultural Mechanization Engineering in the University of Tehran under supervision of Dr. Shahin Rafiee and Dr. Ali Jafari. His research fields include energy optimization in agricultural systems, biosystems engineering, agricultural mechanization and mathematical programming.
E-mail address: mohammadia@ut.ac.ir