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Full Length Research Paper

Input-output energy analysis of citrus production in Mazandaran province of Iran

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In this study, the citrus (orange and mandarin) production in Mazandaran province of Iran and the energy equivalences of input used in this production are investigated. Data in this study was obtained from 110 citrus orchards by a face to face questionnaire method. The results revealed that mandarin production had more energy intensive compared to orange. The major energy inputs in orange and mandarin production were diesel fuel (27 and 24%), chemical fertilizers (22 and 23%) and irrigation water (21 and 23%), respectively. The results showed that 62375.18 MJ ha^{-1} energy were consumed by orange orchards and 77501.17 MJ ha^{-1} by mandarin orchards. Energy use efficiency, energy productivity, specific energy, and net energy gain were calculated. The energy use efficiency for orange and mandarin were 0.99 and 0.77, respectively. In average, the non-renewable form of energy input was 67.14% of the total energy input used in citrus production compared to 33.07% for the renewable form. Optimal consumptions of diesel fuel, chemical fertilizers and other major inputs would be useful techniques for decreasing energy consumption in citrus production.

Key words: Orange, mandarin, energy use efficiency, Iran.

INTRODUCTION

Traditional, low energy farming is being replaced by modern systems, which require more energy use. Historically, the efficient use of energy in agriculture did not have a high priority but recently the use of energy resources has increased markedly with advancement in the technology and general agricultural developments (Chaudhary et al., 2009). The energy ratios in agricultural production are closely related to production techniques, quantity of inputs used by producers and crop yield along with environmental factors such as soil and climate. Therefore, there is a range of energy input and output relationships for the same crop depending on the region (Yilmaz et al., 2005). Effective energy use in agriculture is one condition for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction (Uhlin, 1998; Karimi et al., 2008). Energy input-output analysis in agricultural systems has been widely used to assess the efficiency and the environmental impact (Bojaca and Schrevens, 2010). Energy analyzing can be used as a first step towards identifying crop production processes that benefit most from increased efficiency (Mohammadi et al., 2008). In agricultural production, energy is used in direct and indirect ways (Ozkan et al., 2004a). Efficient use and impacts study of these energies in crop production help to increase production and productivity and help the economy, profitability and competitiveness of agricultural sustainability of rural communities (Singh et al., 2002a).

Many researchers have studied energy analysis to determine the energy efficiency of orchards production, such as citrus (Ozkan et al., 2004a), cherries (Kizilaslan, 2009), apricot (Esengun et al., 2007), sweet cherry (Demircan et al., 2006) in Turkey, walnut in Iran (Banaeian et al., 2010), apple in Greece (Strapatsa et al., 2006), apricot and plum in Italy (Sartori et al., 2005). However, no studies have been published on the energy inputs-output analysis of citrus (orange and mandarin) production in Iran.

The citrus fruit trees belong to the Rutaceae family and Aurantioideae subfamily. The suggested origin of the true

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

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Reference
Input			
Human labor	h	1.96	(Ozkan et al., 2004a)
Machinery	h	62.70	(Ozkan et al., 2004a)
Diesel fuel	l	56.31	(Mohammadi et al., 2008)
Chemical fertilizers:	kg		
a)Nitrogen (N)		66.14	(Mohammadi et al., 2008)
b)Phosphate (P_2O_5)		12.44	(Mohammadi et al., 2008)
c)Potassium (K_2O)		11.15	(Mohammadi et al., 2008)
Farmyard manure	kg	0.30	(Canakci et al., 2005)
Chemicals:	kg	120	(Mohammadi et al., 2008)
a) Pesticides		199	(Ozkan et al., 2004a)
b)Fungicides		92	(Ozkan et al., 2004a)
c)Herbicides		238	(Ozkan et al., 2004a)
Electricity	kWh	11.93	(Ozkan et al., 2004a)
Water for irrigation	m^3	1.02	(Mohammadi et al., 2008)
Output			
Orange	kg	1.90	(Ozkan et al., 2004a)
Mandarin	kg	1.90	(Ozkan et al., 2004a)

citrus fruits is south East Asia, including South China, north-Eastern India and Burma. Different species of citrus genus have undergone a very long period of cultivation (Spiegel-Roy and Goldschmidt, 1996). Nigeria, China, Colombia, Guinea, Syrian Arab Republic, Philippines, Saudi Arabia and India are the major citrus producers. The citrus is also cultivated in Japan, Mexico, Tunisia, Kenya and Iran (FAO, 2010). Citrus 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 (Singh et al., 2002b). 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 (FAO, 2010). Citrus are the most important horticultural crop in Mazandaran province. Today, about 40% of citrus production in Iran is provided in Mazandaran province (Anonymous, 2005).

The objective of the present investigation is to make an input-output energy analysis of citrus production in Mazandaran province situated in northern region of Iran and identify the major energy flows in this system.

MATERIALS AND METHODS

The study was performed in Mazandaran province where all citrus production is concentrated. The Mazandaran province is located in the north of Iran, within 31° 47' and 38° 05' north latitude and 50° 34' and 56° 14' east longitude. Data were collected from 110 citrus orchards using a face to face questionnaire in January 2011. The collected data belonged to the production period of 2010. In addition to the survey results, the results of previous studies were also used in this study. The size of each sample was determined using Equation (1) (Kizilaslan, 2009):

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

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 found to be 110 orchards.

To calculate the energy involved in the production of citrus, the energy analysis technique was used. Recorded data included the duration of each operation and the quantities of each input (machinery, fuel, fertilizers, chemicals, irrigation water, labor, etc.). The amounts of input were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. The energy equivalences of unit inputs are given in Mega Joule (MJ) unit by multiplying inputs with the coefficient of energy equivalent. Table 1 showed energy equivalents were used for estimating inputs and outputs energies in citrus production.

The energetic efficiency of the agricultural system has been evaluated by the energy ratio between the outputs and the inputs. Basic information on energy inputs and citrus were entered into Excel spreadsheets, SPSS 17 spreadsheets. Based on the energy equivalents (Table 1), the energy use efficiency (energy ratio), the energy productivity, the net energy gain and the specific energy were calculated as (Ozkan et al., 2004a):

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (2)$$

Table 2. Amounts of inputs, output and energy inputs and output for orange and mandarin production in Mazandaran, Iran.

Inputs and outputs (unit)	Orange		Mandarin	
	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})
Inputs				
Human labor (h)	1100.00	2156.00	1386.00	2716.56
Machinery (h)	60.00	3762.00	72.00	4514.40
Diesel fuel (l)	300.00	16893.00	330.00	18582.30
Chemical fertilizer (kg)		13600.78		17474.85
a) Nitrogen	94.00	6217.16	135.00	8928.90
b) Phosphate	343.00	4952.92	415.00	5992.60
c) Potassium	218.00	2430.70	229.00	2553.35
Farm yard manure (kg)	16000.00	4800.00	20500.00	6150.00
Chemicals (kg)		3271.75		3777.60
a) Pesticides	4.35	865.65	5.00	995.00
b) Fungicides	3.00	276.00	3.60	331.20
c) Herbicides	8.95	2130.10	10.30	2451.40
Electricity (kWh)	425.00	5070.25	542.00	6466.06
Water for irrigation (m^3)	12570.00	12821.40	17470.00	17819.40
Total energy input (MJ)	-	62375.18	-	77501.17
Output				
Fruits (kg)	32500.00	61750.00	31500.00	59850.00

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

$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Citrus output (kg ha}^{-1})} \quad (4)$$

$$\text{Net energy} = \text{Energy output (MJ ha}^{-1}) - \text{Energy input (MJ ha}^{-1}) \quad (5)$$

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, seed 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, seeds, farmyard manure and water for irrigation energies (Yilmaz et al., 2005). In the last part of the study, direct, indirect, renewable and non-renewable forms of input energy were calculated.

RESULTS AND DISCUSSION

In Table 2, the physical inputs and their energy equivalences used in the production of orange and mandarin are given. Also Table 2 shows output energy rates of orange and mandarin productions. As it can be seen in the Table 2, 94 and 135 kg nitrogen, 343 and 415 kg phosphate, 218 and 229 kg potassium, 16 and 20.50 tons of farm yard manure, 300 and 330 l diesel fuel, 12570 and 17470 m^3 water, 16.30 and 18.90 kg chemical spraying agents, 1100 and 1386 h human labor, 60 and 72 h machinery, 425 and 542 kWh electrical energy per hectare are used for the production of orange and mandarin respectively. The average oranges and mandarins output were found to be 32500 and 31500 kg ha^{-1} respectively in the enterprises that were analyzed.

Energy analysis revealed that total energy used in various farm operations during orange and mandarin productions were 62375.18 and 77501.17 MJ ha^{-1}, respectively (Table 2).

Distribution of the anthropogenic energy input ratios in the production of oranges and mandarins are given in Figures 1 and 2, respectively. As can be seen in the Figure 1, energy used in the production of oranges consists of 5% chemicals, 3% human labor, 6% machinery, 22% chemical fertilizers, 27% fuel (diesel), 8% electricity, 8% farm yard manure and 21% water inputs. The highest energy input is provided by diesel fuel followed by chemical fertilizer (Figure 1). From Table 2 and Figure 1, it is shown that human labor was the least

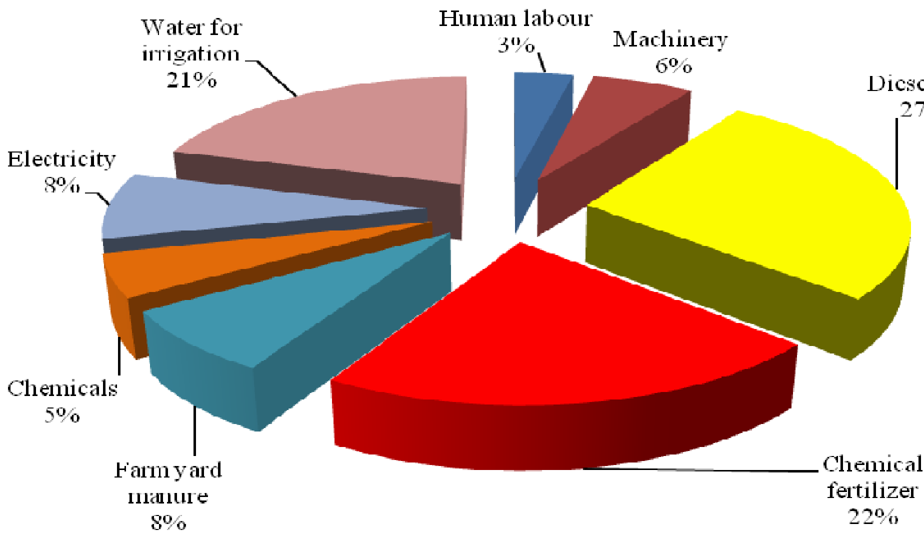

Figure 1. The anthropogenic energy input ratios in the production of oranges.

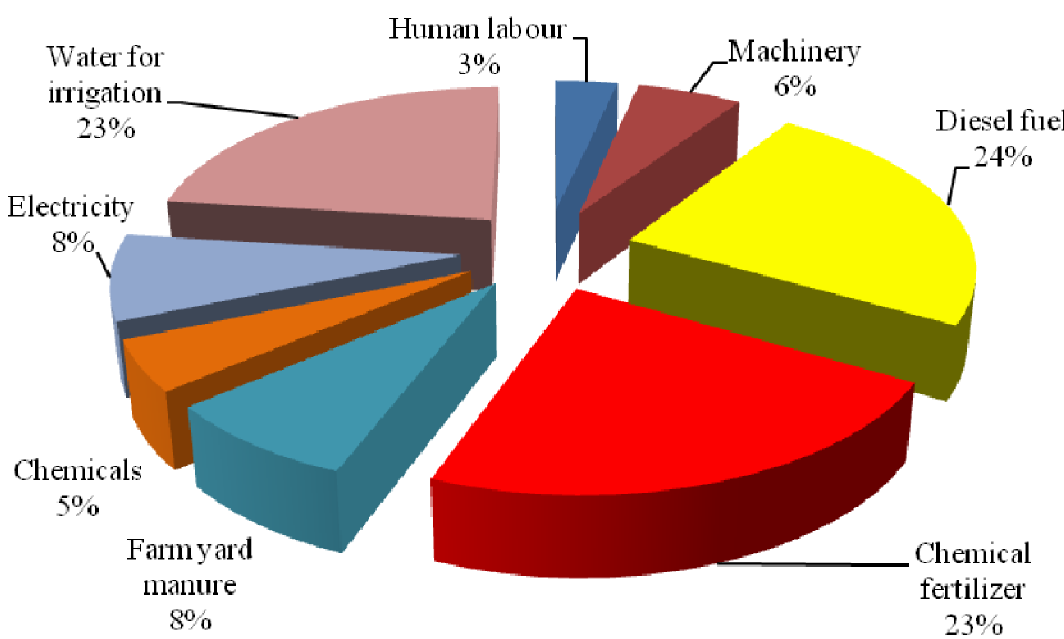

Figure 2. The anthropogenic energy input ratios in the production of mandarins.

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%).

Similarly, energy used in the production of mandarins consists of 5% chemicals, 3% human labor, 6% machinery, 23% chemical fertilizers, 24% fuel (diesel), 8% electricity, 8% farm yard manure and 23% water inputs. In these operational inputs, the highest energy requirements were found for diesel fuel, chemical fertilizer and water for irrigation with shares of 24, 23 and 23%, respectively. In mandarin production, human labor was the least demanding energy input followed by chemicals.

Similar results were reported by some researchers, like Mohammadi et al. (2008) for potato production, Ozkan et al. (2004a) for orange, mandarin and lemon productions, Yilmaz et al. (2005) for cotton, Esengun et al. (2007) for stake-tomato, while Banaeian et al. (2011) for green-house strawberry reported that the highest energy input is provided by diesel fuel followed by fertilizers.

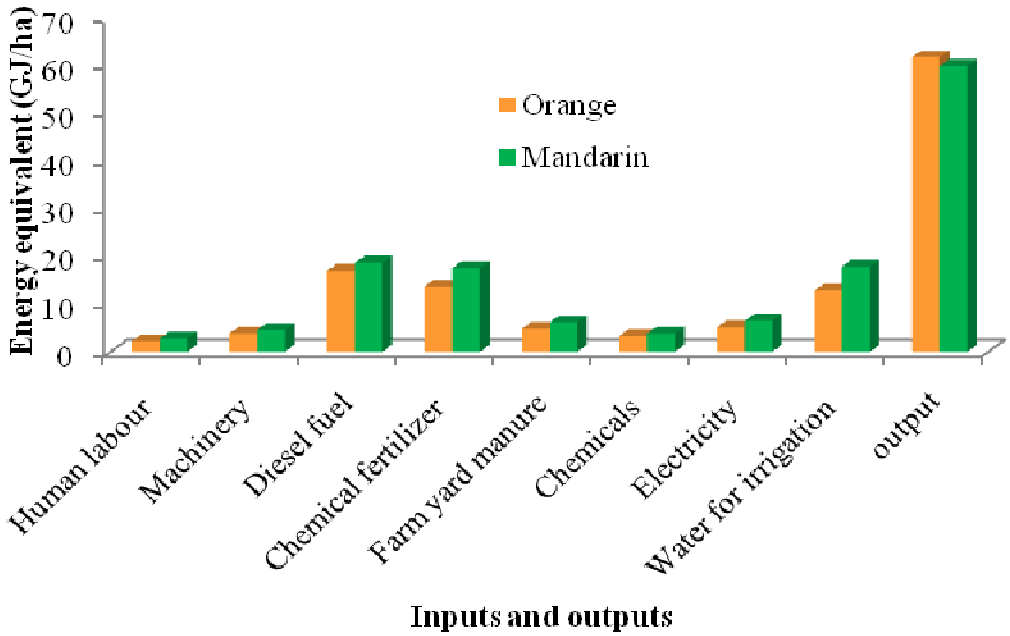

Figure 3. Comparison of the energy inputs and output in orange and mandarin productions.

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

Item	Unit	Orange	Mandarin
Energy use efficiency	-	0.99	0.77
Energy productivity	kg MJ^{-1}	0.52	0.41
Specific energy		1.92	2.46
Net energy gain	MJ ha^{-1}	-625.18	-17651.17
Direct energy[a]	MJ ha^{-1}	36940.65 (59.22%)	45584.32 (58.82%)
Indirect energy[b]	MJ ha^{-1}	25434.53 (40.78%)	31916.85 (41.18%)
Renewable energy[c]	MJ ha^{-1}	19777.4 (31.71%)	26685.96 (34.43%)
Non-renewable energy[d]	MJ ha^{-1}	42597.78 (68.71%)	50815.21 (65.57%)
Total energy input[e]	MJ ha^{-1}	62375.18 (100%)	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.

Results of this study revealed that diesel fuel, chemical fertilizer and water for irrigation was mainly consumer of energy in producing orange and mandarin (Figures 1 and 2). 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. It is clear that the mean yield of electricity, chemicals, farm yard manure, machinery and human labor inputs remained at low levels compared to the diesel consumption, fertilizer applications and water for irrigation (Figures 1 and 2).

The mean yield of oranges and mandarins was 32.5 and 31.5 tons, respectively. Energy output in orange and mandarin productions were 61750 and 59850 MJ ha^{-1}, respectively (Table 2).

Comparison of the energy inputs and output in orange and mandarin productions are given in Figure 3. As can be seen, the maximum energy is required (in all inputs) in mandarin production compared to orange production while energy output of orange is more than mandarin (Figure 3).

The energy use efficiency (energy ratio) in the production of oranges and mandarins were found as 0.99 and 0.77 (Table 3). In previous investigations, Ozkan at al. (2004a) in Turkey calculated energy ratio as 1.25 and 1.17 for orange and mandarin production, respectively.

Energy ratio of orange is more than mandarin production (Table 3). This is accordance with results of Ozkan et al. (2004 a). Similar results were reported by Ozkan et al. (2004a) for lemon (1.06), 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). The average energy productivity of orange and mandarin orchards was 0.52 and 0.41 kg MJ^{-1}, respectively. This means that for example in orange production 0.52 kg output was obtained per unit energy (MJ). The comparison between the two citruses shows orange orchards can produce 0.11 output more than mandarin orchards. 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), tomato (0.32 and 0.27) (Zangeneh et al., 2010). Specific energy in orange production was calculated as 1.92 MJ kg^{-1} and in mandarin as 2.46 MJ kg^{-1}, respectively. Other researchers reported similar values for specific energy such as 5.24 for wheat, 3.88 for maize, 1.14 for tomato in Turkey (Canakci et al., 2005) and 3.97 and 4.72 for potato in Iran (Zangeneh et al., 2010).

The net energy in orange and mandarin production was -625.18 and -17651.17 MJ ha^{-1}, respectively. Therefore, it is concluded that in orange and mandarin production in Mazandaran province, energy had 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 citrus production in Mazandaran province 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.

Also the distribution of inputs used in the production of citrus according to the direct, indirect, renewable and non-renewable energy groups, are given in Table 3. As it can be seen from the table, the total energy input consumed could be classified as direct (59.22 and 58.82%), indirect (40.78 and 41.18%), renewable (31.71 and 34.43%) and non-renewable (68.71 and 65.57%) in orange and mandarin production, respectively. Similarly, Ozkan et al. (2004 a) have found that the ratio of direct energy is higher than that of indirect energy, and the rate of non-renewable energy was greater than that of renewable energy consumption in orange and mandarin production in Turkey. As can be seen from Table 3, the maximum direct energy is used in mandarin production followed by orange. On average, the share of direct energy in citrus production was 59.02% while indirect energy was 40.98%. Direct inputs are mainly diesel fuels for pumping water and field operations, and the indirect inputs are dominated by fertilizer use. It can be pointed out that fertilizer management, to reduce the indirect energy requirements for fertilizer manufacture and tractor selection and operation to reduce the direct use of diesel seem to be the most significant areas for improving overall energy efficiency of the Iran citrus fruit industry. The results indicate that the current energy use pattern among the investigated orchards is based on non-renewable energy in the citrus production. In other words, the proportion of renewable energy use in the surveyed orchards is low. As can be seen from the Table 3, on average, the non-renewable form of energy input was 67.14% of the total energy input compared to 33.07% for the renewable form. This indicates that citrus production depends mainly on fossil fuels in the research area. Therefore, it implies that Iran citrus production is very sensitive to possible changes in the price of fossil fuels and their supply availability. A reduction in the total non-renewable energy ratio, specifically in fuel consumption would have positive effects on the sustainability of citrus production as well as other positive environmental effects.

Results of this study showed the major energy inputs in citrus production in Iran are diesel fuel, chemical fertilizer and water for irrigation. It is normal practice in intensive large farming systems in Iran to use more inputs to ensure high yields. But there were some techniques for improving energy efficiency and reducing energy inputs. In the following, techniques to reduce energy inputs for a sustainable citrus production are discussed.

Diesel fuel

Fuel account for 25.50% of the energy inputs for citrus production in Iran. On the other hand, the consumption of fossil energy results in direct negative environmental effects through release of CO_2 and other combustion gases (Zangeneh et al., 2010). The major part of fuel consumption is associated with pumping water and operating tractors. In the research area, use electricity power for pumping water can reduce energy inputs and environmental impact issues compared to the diesel power. Research on optimum tillage techniques suitable for local conditions, timing of tillage and matching the size and power of tractors and other machinery to field operations are also important factors in reducing fuel consumption (Karimi et al., 2008).

Chemical fertilizer

The determination of the exact citrus nutrients needs through soil, then applying fertilizers accordingly is a good way for reducing chemical fertilizers. The decline in soil organic matter leads to the use of greater amounts of chemical fertilizers than normal. Green manuring is another area that should be explored (Karimi et al., 2008).

Water for irrigation

It is necessary that agriculture uses alternative and more efficient water systems. Furrow irrigation, plus drip irrigation and micro-irrigation and other new water-saving irrigation technologies should also be considered (Karimi et al., 2008).

Conclusions

In this study, energy use pattern in citrus (orange and mandarin) production in Mazandaran province of Iran were investigated. Total energy consumption of orange and mandarin was 62375.18 and 77501.17 MJ ha^{-1}, respectively. The major energy inputs in citrus production were diesel fuel, chemical fertilizers and water for irrigation. Mandarin consumed more input energy than orange while output energy was higher in the orange. Therefore energy use efficiency and energy productivity of the orange orchards were higher than those of the mandarin orchards. The results further revealed that net energy in orange and mandarin production was negative. Based on the structure of orchard system and the level of technology in citrus orchards, this negative value is reasonable. The total energy input consumed could be classified as direct (59.22 and 58.82%), indirect (40.78 and 41.18%), renewable (31.71 and 34.43%) and non-renewable (68.71 and 65.57%) in orange and mandarin production, respectively. The amount of non-renewable energy in both fruits was rather high. Therefore optimal consumptions of diesel fuel, chemical fertilizers and other major inputs would be useful not only in reducing negative effects to environment and human health, but maintaining sustainability and decreasing energy consumption. Agricultural advising should also be activated.

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