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ORIGINAL ARTICLE

Energy Analysis and Emissions of Greenhouse Gases of Pomegranate Production in Antalya Province of Turkey

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Abstract

In this study, energy use patterns and the functional relationship between energy inputs and output for pomegranate production were investigated in Antalya province in Turkey. It further objective to identify greenhouse gas (GHG) emissions in pomegranate production. Data were obtained from 75 farms using face-to-face interview method. The results indicated that 50,605.5 MJ · ha^{-1} of total energy input was required for 76,252.3 MG · ha^{-1} pomegranate energy output. 1.51 unit energy output was provided by using 1 unit energy input. 1 unit energy output and 1 kg pomegranate require 0.66 unit and 2.57 MJ energy input, respectively. The average CO_2 emission amounts were also calculated to be 1.73 t CO_2 per hectare and 88.1 kg CO_2 per 1000 kg pomegranate production. Electricity, fertilizers and pesticides were the highest contributors to GHG emissions. Both total energy input usage and GHG emission amounts have been found to be decreasing as the farm size increases. Increasing scale of pomegranates orchards will not only increase energy efficiency and productivity but also decrease environmental pollution and damages. The regression analysis revealed that, excessive use of machinery and fuel inputs results in a decline in energy production in pomegranate.

Keywords Energy analysis · Energy productivity · Greenhouse gases · Energy production function · Pomegranate

Energiebilanz und Treibhausgasemissionen bei der Produktion von Granatapfel in der Provinz Antalya, Türkei

Schlüsselwörter Energiebilanz · Energieproduktivität · Treibhausgase · Energieerzeugungsfunktion · Granatapfel

Introduction

Turkey is within the borders of the homeland of pomegranate, and has been producing and consuming this fruit for thousands of years. Pomegranate cultivation has been popular particularly in recent years in Turkey. The production area, which was 4675 ha in 2000, reached to 30,751 ha in 2015, with an annual increase rate of 13.4%. In parallel to the increase in production area, the total pomegranate production rose from 59,000 to 445,750 tons in the same period (TUIK 2016). Antalya climbed from the tenth place to the top among provinces with an annual increase rate of 13.4%, in pomegranate production in Turkey.

Nowadays agricultural sector has become more energy intensive in order to provide not only food but also energy (biogas and electricity) for increasing population and welfare. The energy consumption in Turkish agriculture, which was 3073 Mep in 2000, increased to 5755 Mep in 2011 with an annual increase rate of 5.9% (Ozturk et al. 2015). Intensive, excessive and unconsciously energy input use in agriculture results in a decrease in profitability and an increase in human health risk. Moreover, it creates numerous environmental problems such as pollution of water by chemical fertilizer and pesticides, greenhouse gas emission (GHG) that leads to global warming. Agriculture contributes significantly to atmospheric GHG emissions, by producing 14% of the global net CO_2 emission (IPCC 2007). Therefore, en-

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ergy analysis and GHG emission assessments are well-established components of environmental impact assessments (Yousefi et al. 2014). Energy analyses, based on the ratios and econometrics are generally used for measuring energy efficiency and its environmental impacts. These analyses help to determine how efficiently energy is used. Thus, both the unnecessary use of energy and the damages suffered by the environment can be reduced (Goktolga et al. 2006; Barut et al. 2011). Moreover, the effective energy use in agriculture is a fundamental condition for sustainable agricultural development, since it provides financial savings and preserves natural resources by decreasing production costs and pollution (Uhlin 1998; Flores et al. 2016).

In recent years, many studies have been conducted on energy analysis of different fruits. Some of these studies are on apple production in Greece (Strapatsa et al. 2006), in Iran (Rafiee et al. 2010); sultana grape (Kocturk and Engindeniz 2009), cherry (Kizilaslan 2009), sweet cherry (Demircan et al. 2006), banana (Gundogmus 2013) production in Turkey; kiwifruit (Mohammadi et al. 2010), tangerine (Mohammadshirazi et al. 2012), peach (Royan et al. 2012), nectarine (QasemiKordkheili et al. 2013), mango production in Nigeria (Jekayinfa et al. 2013). In some particular studies, the use of energy in the production of pomegranate in Turkey is studied (Akcaoz et al. 2009; Canakci 2010). Distinctively from both studies, this study considered GHG emissions during production, econometric energy analysis and the effect of the farm groups on energy use. In addition, the differences among farm group mean values were statistically tested.

The aims of this study are (1) to investigate the input-output energy balances and to determine of scale effect (2) to estimate GHG emissions of pomegranate production to contribute to climate change mitigation efforts, (3) to specify a relationship between input energies and output, in addition to functional analysis of the energy inputs on pomegranate production in Antalya, Turkey.

Material and Method

Main material of this study consists of the data obtained through surveys conducted with the producers cultivating pomegranate in the sub-provinces of Antalya, almost 73.2% of the pomegranate production that takes place in Antalya. Furthermore, the information derived from previously-conducted studies is utilized. Within the scope of the study, face-to-face interviews were conducted with 75 pomegranate producers, 28 of which were from Group 1 (0.01–1.0 ha) enterprises, 16 of which were from Group 2 (1.1–2.0 ha) enterprises, 15 of which were from Group 3 (2.1–4.0 ha) enterprises, and 16 of which were from Group 4 (above 4 ha) enterprises. Sample farms were randomly selected from the villages in the region by using a stratified random sampling method. So, weighted average values represented the region. The sample size has been calculated using the Neyman method and the permissible error in the sample population have been defined to be 5% within 95% confidence interval.

Total energy input per unit area (hectare) is composed of the sum of partial energy of each input used in the production. The input categories studied consist of human labour, diesel fuel, electricity, agricultural tools and machineries, farm manure, irrigation water, chemical fertilizer (N, P, K) and agricultural pesticides. The units shown in Table 1 are used to find the quantities of the inputs used in production. Input quantities per hectare are calculated, and then such input data are multiplied by the energy equivalent factor. Energy equivalents of unit inputs are represented in Mega Joules (MJ). Total input equivalent can be calculated by summing the energy equivalents of all inputs represented in MJ.

Net energy, energy use efficiency, energy productivity and specific energy ratios are calculated using the formulas given below (Yousefi et al. 2014; Mandal et al. 2002; Houshyar et al. 2015; Sefeedpari et al. 2014):

$$\text{Net energy}\ \left(\text{MJ}\cdot\text{ha}^{-1}\right) = \text{Energy Output}\ \left(\text{MJ}\cdot\text{ha}^{-1}\right) - \text{Energy Input}\ \left(\text{MJ}\cdot\text{ha}^{-1}\right) \tag{1}$$

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

$$\text{Energy productivity}\ \left(\text{kg}\cdot\text{MJ}^{-1}\right) = \frac{\text{Pomegranate production}\ \left(\text{kg}\cdot\text{ha}^{-1}\right)}{\text{Energy Input}\ \left(\text{MJ}\cdot\text{ha}^{-1}\right)} \tag{3}$$

$$\text{Specific energy}\ \left(\text{MJ}\cdot\text{kg}^{-1}\right) = \frac{\text{Energy Input}\ \left(\text{MJ}\cdot\text{ha}^{-1}\right)}{\text{Pomegranate production}\ \left(\text{kg}\cdot\text{ha}^{-1}\right)} \tag{4}$$

In addition to farm size group, farm and farmers are classified with respect to their locations in sub regions ((1) Dosemealtı, (2) Kepez, Konyaaltı, Muratpasa, Aksu and (3) Serik), and education levels ((1) primary education, (2) secondary education and (3) university) in this study. The differences of the estimated mean values of the energy inputs, outputs per hectare and the energy efficiency and productivity ratios by groups are also statistically tested. Variance analysis and its non-parametric alternative, Kruskal-Wallis tests are used to statistically test. The assumptions of the one-way analysis of variance for independent samples are; (a) the dependent variable is measured has the properties of an equal interval scale; (2) that more than two (k) samples are independently and randomly drawn from the populations; (3) that the populations have a normal distribution; and (4) that the k samples have ap-

Table 1 Energy equivalents and greenhouse gas (GHG) emissions coefficients of agricultural inputs and output

Inputs and output (Unit)	Energy equivalent factor (MJ/unit)	GHG coefficient (kg $CO_{2eq} \cdot unit^{-1}$)
1. Human labour (h)	1.96 (Singh et al. 2001)	0.36 (Houshyar et al. 2015)
2. Farm Machinery (kg)		
Machines	121.3 (Barut et al. 2011)	0.071 (Komleh et al. 2011)
Tractor	158.3 (Barut et al. 2011)	
3. Fertilizers (kg)		
Nitrogen	60.6 (Singh 2002)	1.30 (Lal 2004)
Phosphorus	11.1 (Mandal et al. 2002)	0.20 (Lal 2004)
Potassium	6.70 (Mandal et al. 2002)	0.20 (Taghavifar and Mardani 2015)
4. Farm manure (kg)	0.30 (Ertekin et al. 2011)	0.005 (Mohammadi et al. 2014)
5. Chemicals (kg)		
Insecticids, acaroids	184.2 (Hetz 1992)	5.10 (Lal 2004)
Funguicides	216.0 (Erdal et al. 2007)	3.90 (Graefe et al. 2013)
Herbicides	238.0 (Erdal et al. 2007)	6.30 (Graefe et al. 2013)
6. Fuel (diesel) (l)	47.80 (Hetz 1998)	2.76 (Dyer and Desjardins 2003)
7. Electricity (kWh)	10.59 (Canakci and Akinci 2006)	0.608 (Khoshnevisan et al. 2013)
8. Irrigation water (m^3)	0.63 (Yaldiz et al. 1993)	0.27 (Houshyar et al. 2015)
Pomegranate (kg)	2.40 (Akcaoz et al. 2009)	–
By product, Branch (kg)	18.00 (Singh 2002)	–

proximately equal variances (Lowry 1999; Arsham 2002). First two assumptions were achieved during the survey stage of the study. Normality assumption tested using Kolmogrov-Smirnov and Shapiro-Wilk tests (Baldwin 2002). Any failure of the assumptions Kruskal-Wallis tests was used.

CO_2 emission coefficients of different agricultural inputs are used in order to quantify the GHG emissions of pomegranate cultivation. Table 1 also summarizes GHG emission equivalents and the emission amounts calculated by multiplying the input data by its corresponding emission coefficient.

In order to specify a relationship between energy inputs and energy production, a mathematical function is required. For this purpose, Cobb-Douglass production function is chosen as the best function in terms of statistical significance and expected signs of parameters. The Cobb-Douglass production function has been used by some authors to investigate the relationship between inputs and energy production (Rafiee et al. 2010; Mohammadi et al. 2010; Singh et al. 2004; Erdal et al. 2009; Samavatean et al. 2011). The Cobb-Douglass production function is expressed as follows;

$$Y = \beta_0 \prod X_{ji}^{\beta_j} e^{ui}, (i : 1, ..., n; j : 1, ..., k) \quad (5)$$

This function can be expressed as a linear relationship using the following expression:

$$\ln Y = \beta_0 + \sum_{j=1}^{n} \beta_j \ln X_{ji} + e, (i : 1, ..., n) \quad (6)$$

where: Y_i denotes the production of the *i*th producer, X_{ij} is the vector of inputs used in the production process, β_0 is a constant term, β_j represent coefficients of inputs which are estimated from the model and e_i is the error term.

Assuming that pomegranate energy production is a function of inputs, for investigating the impact of each input on pomegranate energy production, the Eq. 6 can be expanded in the following form;

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + e_i \quad (7)$$

where; Y_i represents pomegranate energy production, X_i ($i=1, ...,7$) represents physical inputs from human labour (X_1), machinery (X_2), diesel fuel (X_3), chemical fertilizer (X_4), pesticides (X_5), electricity (X_6), and pomegranate land (X_7).

The Cobb-Douglass energy production function (Eq. 7) is estimated using Ordinary Least Square (OLS) method. The analysis is performed using the statistical software package. After the estimation of the energy production function, marginal physical productivities (MPP) of the various inputs are calculated using the β_j of the various inputs as follows:

$$MPP_{xj} = \beta_j \frac{Gm\,Y}{Gm\,X_j} \quad (8)$$

where MPP_{xj} is marginal physical productivity of *j*th input, β_j regression coefficient of *j*th input, G_m Y geometric mean of production and $G_m X_j$, geometric mean of *j*th input energy.

Results and Discussion

The average family size is 5.1 in the study. It is also found that 52.4% of the family population constituted male and 47.6% female. The average age of pomegranate farmers interviewed is 49.9. More than half of the surveyed farmers (55.1%) have primary education, 22.8% have secondary education and 22.1% have university level education. The average duration of experience of pomegranate production in the enterprises surveyed is found to be 8.1 years. The average pomegranate garden size was calculated as 0.21 hectares in the surveyed farms. The average number of trees in the orchard was 55.5. The characteristic structure of pomegranate cultivation in the research area is small family farming.

Energy Inputs and Outputs in Pomegranate Production

Total physical energy input consists of human labour, machinery, chemical fertilizer, farm manure, pesticides, diesel, electricity and water for irrigation. Physical energy sources and energy consumption for pomegranate production are presented in Table 2. The results revealed that, the quantity of labour and machinery power used in the pomegranate production are 912.0 h · ha^{-1} and 85.3 h · ha^{-1}, respectively. Total hours of labour used in different operations are as follows: for harvesting 407.5 h, maintenance 281.8 h, irrigation 103.4 h, fertilizing 54.0 h, spraying 43.9 h and soil cultivation 21.4 h per hectare. Chemical fertilizers are typically applied 3.44 times and 549.6 kg per hectare a year. Additionally, 932.0 kg of farm manure per hectare is used. The chemical fertilizers consist of nitrogen (46.3%), phosphorus (29.9%) and potassium (23.8%). The total amount of pesticide used in pomegranate production is 69.3 kg per hectare. The share of insecticides, fungicides, herbicides and acaroids are found to be 34.8%, 34.6%, 15.9% and 14.8% respectively. Additionally, 35.7 L diesel fuel, 933.6 kWh electricity, 56.9 m^3 water are used per hectare for pomegranate production.

Average pomegranate yield is 19,696.8 kg per hectare in the research area. Pomegranate yields were reported as 23,350 kg · ha^{-1}, between 28,335–43,655 kg · ha^{-1} in previous studies (Akcaoz et al. 2009; Canakci 2010) and 18,691.2 kg · ha^{-1} in 2015 in Antalya (TUIK 2016).

With respect to the obtained results, the shares of weighted average energy consumption in pomegranate production are 35.8% chemical fertilizer, 27.9% pesticides, 19.5% electricity, 9.2% machinery, 3.5% human labour, 3.4% diesel, 0.6% farm manure and 0.1% water for irrigation. Although, percentages vary between different size groups, the general tendency is that the chemical fertilizers and pesticides are the highest energy inputs in all groups. There are percentage differences between the groups in terms of other inputs as well, but the ranking is similar to the average size groups. The results revealed that consumption of fertilizer, pesticides, electricity and machinery energy inputs is relatively high for pomegranate production in the region.

When we examine the operations in human labour, the highest energy is consumed in harvesting (44.7%) and hoeing, pruning (30.9%). Fertilization (50.1%) is the highest energy input in machinery usage. Nitrogen (85.1%) is the main fertilizer, the fungicides (36.7%) and insecticides (31.3%) are the main pesticides in pomegranate production.

Energy uses per hectare have been found 29.1% higher on the smallest size group farms than the largest size group. These results are consistent with the results for cotton production by Yilmaz et al. (2005). Moreover, in this study in all categories of energy inputs, least energy is being used in the largest size group. In general, differences in all means of energy inputs have been found statistically significant with respect to farm size groups. However, there are no significant differences with respect to sub regions and farmer education levels.

The average energy input, output and the amount of net energy have been calculated as 50,605.3 MJ · ha^{-1}, 76,252.3 MJ · ha^{-1} and 25,647.1 MJ · ha^{-1}, respectively in this study. However, energy use and net energy per hectare is 45.2% higher on the largest size group farms than the smallest size group because of the scale effect. It is also reported that large farms used energy in the best possible way to achieve maximum yield (Singh et al. 1996). Variance analysis results show that there are significant differences only in terms of total energy outputs with respect to sub regions ($p = 0.03$). However, the differences in terms of total energy and net energy outputs with respect to size groups and farmer education levels have not been found statistically significant.

The energy inputs and outputs for pomegranate production in previous studies in Turkey were 53,764.6 MJ · ha^{-1} and 56,040 MJ · ha^{-1} (Akcaoz et al. 2009), and between 32,619–44,462.7 MJ · ha^{-1} and 63,395–82,945 MJ · ha^{-1} (Canakci 2010), respectively. In literature, the results showed that total energy input were 48,667.0 MJ · ha^{-1} for cherries production in Turkey (Kizilaslan 2009), 42,819.3 MJ · ha^{-1} for apple production in Iran (Rafiee et al. 2010), between 192,652.6–168,783.9 and 76,433.3–42,995.6 MJ · ha^{-1} for plum production in Iran (Tabatabaie et al. 2012), 15,015.2 and 20,400 MJ · ha^{-1} for mango production in Nigeria (Jekayinfa et al. 2013).

Table 2 Physical and energy inputs and outputs for pomegranate production

Inputs/Output (Unit)	Quantity Per ha	Energy equivalent by size groups ($MJ \cdot ha^{-1}$) 1	2	3	4	Average	%	*p*
I. Inputs								
1. Human labour (h)	*912.0*	*1952.7*	*1668.5*	*1495.5*	*1279.5*	*1787.5*	*3.5*	–
Soil cultivation	21.4	43.7	44.5	34.5	25.9	41.9	0.1	0.05
Hoeing. pruning etc	281.8	572.7	537.6	526.7	461.8	552.3	1.1	0.01
Fertilization	54.0	139.0	77.6	50.0	22.1	105.8	0.2	0.00
Spraying	43.9	107.0	70.4	41.6	44.3	86.0	0.2	0.00
Irrigation	103.4	264.0	152.3	93.1	53.7	202.7	0.4	0.00
Harvesting	407.5	826.3	786.2	749.7	671.7	798.7	1.6	0.01
2. Machinery (h)	*85.3*	*6403.2*	*5024.0*	*3126.3*	*2656.2*	*4660.4*	*9.2*	–
Soil cultivation	16.5	401.6	332.2	237.2	181.0	307.6	0.6	0.00
Hoeing. pruning etc	19.3	1075.5	934.4	642.4	529.1	843.7	1.7	0.00
Fertilization	33.0	3373.3	2596.3	1360.8	1166.5	2336.8	4.6	0.01
Farm manure tran	7.8	731.4	445.7	197.9	174.7	445.3	0.9	0.00
Harvesting	8.7	821.4	715.4	688.0	604.9	727.0	1.4	0.01
3. Chemical fertilizer[a] (kg)	*549.6*	*18,116.7*	*15,664.8*	*23,693.9*	*16,125.2*	*18,127.7*	*35.8*	–
Nitrogen	254.6	15,028.8	13,586.5	20,985.8	14,713.7	15,428.8	30.5	0.09
Phosphorus	164.2	2109.0	1394.2	1781.6	851.4	1822.6	3.6	0.06
Potassium	130.8	978.9	684.1	926.6	560.1	876.4	1.7	0.08
4. Farm manure	*932.0*	*294.8*	*274.8*	*245.9*	*217.9*	*279.6*	*0.6*	*0.00*
5. Pesticides[b] (kg)	*69.3*	*15,265.0*	*13,160.7*	*12,440.8*	*11,188.2*	*14,120.1*	*27.9*	–
Insecticides	24.1	4512.9	4549.7	4034.0	3923.5	4420.8	8.7	0.28
Fungicides	24.0	5292.0	5335.2	4730.4	4600.8	5184.0	10.2	0.00
Herbicides	11.0	2641.8	2594.2	2737.0	2332.4	2618.0	5.2	0.75
Acaroids	10.3	2818.3	681.5	939.4	331.6	1897.3	3.7	0.00
6. Fuel (l)	*35.7*	*2006.8*	*1931.0*	*1224.9*	*1418.0*	*1706.0*	*3.4*	*0.01*
7. Electricity (kWh)	*933.7*	*10,859.6*	*8723.1*	*8146.8*	*9624.7*	*9888.1*	*19.5*	*0.01*
8. Irrigation water (m^3)	*56.9*	*35.8*	*35.8*	*35.8*	*35.8*	*35.8*	*0.1*	*1.00*
Total input	–	54,934.6	46,482.7	50,409.9	42,545.4	50,605.3	100.0	1.00
II.								
1. Pomegranate (kg)	19,696.8	48,176.4	44,303.8	49,390.1	46,880.9	47,272.3	62.0	0.27
2. Branches (kg)	1610.0	29,534.2	27,160.1	30,278.3	28,740.0	28,980.0	38.0	0.35
Total output	–	77,710.6	71,463.9	79,668.4	75,620.9	76,252.3	100.0	0.43
Net energy	–	22,776.1	24,981.2	29,258.5	33,075.5	25,647.1	–	0.39

[a]Total plant nutrients
[b]Active ingredients

Table 3 Energy input-output ratios in pomegranate production by size groups

Indicators	Size groups 1	2	3	4	Average	*p*
Energy use efficiency	1.41	1.54	1.58	1.78	1.51	0.40
Energy productivity ($kg \cdot MJ^{-1}$)	0.37	0.40	0.41	0.46	0.39	0.44
Input/output ratio	0.71	0.65	0.63	0.56	0.66	0.32
Specific energy ($MJ \cdot kg^{-1}$)	2.74	2.52	2.45	2.18	2.57	0.39

Estimated energy productivity and efficiency indicators were given in Table 3 based on the ratios. In our study, average energy use efficiency (output/input) ratio has been found to be 1.51. In other words, 1.51 unit energy output is provided by using 1 unit energy input. In the research area, energy productivity is 0.39 $kg \cdot MJ^{-1}$. Thus, in order to produce 0.39 kg pomegranate, 1 unit energy is consumed. In addition, according to research results, energy input/output ratio is 0.66, and specific energy is 2.57 $MJ \cdot kg^{-1}$. In other words, 1 unit energy output requires 0.66 unit energy input, and 1 kg pomegranate requires 2.57 MJ energy input. In previous studies conducted in the same region, energy

Table 4 Greenhouse gas (GHG) emissions per hectare (kg $CO_{2eq} \cdot ha^{-1}$) and per 1000 kg pomegranate production (kg $CO_{2eq} \cdot 1000\,kg^{-1}$)

Inputs	GHG emissions per hectare					GHG emissions per 1000 kg pomegranate				
	Size groups				W A[a]	Size groups				W A[a]
	1	2	3	4		1	2	3	4	
1. Machinery	*454.6*	*356.7*	*222.0*	*188.6*	*330.9*	*22.6*	*19.3*	*10.8*	*9.7*	*16.8*
Soil cultivation	28.5	23.6	16.8	12.9	21.8	1.4	1.3	0.8	0.7	1.1
Hoeing. pruning etc	76.4	66.3	45.6	37.6	59.9	3.8	3.6	2.2	1.9	3.0
Fertilization	239.5	184.3	96.6	82.8	165.9	11.9	10.0	4.7	4.2	8.4
Farm manure tran	51.9	31.6	14.1	12.4	31.6	2.6	1.7	0.7	0.6	1.6
Harvesting	58.3	50.8	48.8	42.9	51.6	2.9	2.8	2.4	2.2	2.6
2. Chemical fertilizer	*389.6*	*337.0*	*510.0*	*347.7*	*390.0*	*19.4*	*18.3*	*24.8*	*17.8*	*19.8*
Nitrogen	322.4	291.5	450.2	315.6	331.0	16.1	15.8	21.9	16.2	16.8
Phosphorus	38.0	25.1	32.1	15.3	32.8	1.9	1.4	1.6	0.8	1.7
Potassium	29.2	20.4	27.7	16.7	26.2	1.5	1.1	1.3	0.9	1.3
3. Farm manure	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
4. Pesticides	*365.0*	*323.9*	*290.5*	*235.7*	*337.8*	*18.2*	*17.5*	*14.1*	*12.1*	*17.2*
Insecticides	125.0	126.0	111.7	108.6	122.4	6.2	6.8	5.4	5.6	6.2
Fungicides	92.0	110.4	80.3	56.2	93.6	4.6	6.0	3.9	2.9	4.8
Herbicides	69.9	68.7	72.5	61.7	69.3	3.5	3.7	3.5	3.2	3.5
Acaroids	78.0	18.9	26.0	9.2	52.5	3.9	1.0	1.3	0.5	2.7
5. Fuel	*115.9*	*111.5*	*70.7*	*81.9*	*98.5*	*5.8*	*6.0*	*3.4*	*4.2*	*5.0*
6. Electricity	*623.5*	*500.8*	*467.7*	*552.6*	*567.7*	*31.1*	*27.1*	*22.7*	*28.3*	*28.8*
7. Irrigation water	*9.7*	*9.7*	*9.7*	*9.7*	*9.7*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
Total	*1958.2*	*1639.6*	*1570.5*	*1416.1*	*1734.6*	*97.6*	*88.8*	*76.3*	*72.5*	*88.1*

[a]Weighted average

use efficiency ratios were calculated to be 1.04 (Akcaoz et al. 2009), and between 1.91 and 2.84 (Canakci 2010). In these studies, energy productivity was calculated to be 0.43 (Akcaoz et al. 2009), and between 0.66 and 1.02 (Canakci 2010). The energy use efficiency ratio was found to be 1.24–1.31 in the apricot (Esengun et al. 2007) and 2.69 in the apple (Yilmaz et al. 2010) in Turkey.

According to the results, energy use efficiency and energy productivity indicators increase as farm size increases, with the highest efficiency and productivity on large farms. Unlike energy use, efficiency and energy productivity, energy input/output ratio and specific energy decrease as farm size increases. Thus, these results indicate that energy inputs have been used more efficiently and productive in large farms in pomegranate production. Although there are differences in energy use efficiency, energy productivity, energy input/output ratio and specific energy with respect to size groups, sub regions and farmer education levels, they have not been found statistically significant.

Greenhouse Gases Emissions

Table 4 shows the CO_2 emission for pomegranate production according to the energy usage. The average CO_2 emission amount is 1.73 t $CO_{2eq} \cdot ha^{-1}$ in this study. Results indicate that electricity had the highest share in CO_2 emission (32.7%) followed by chemical fertilizers (22.5%), pesticides (19.5%) and machinery (19.1%). It can be seen in Table 4, the total amount of CO_2 emission ranges from 1.42 to and 1.96 t CO_2 per hectare by size group. Parallel to total energy input, the CO_2 emission decreases as farm size increases, with the smallest amounts of CO_2 emission on large farms. The CO_2 emission analysis for different products given in the literature is as follows; the total GHG emission was 1.2 t $CO_{2eq} \cdot ha^{-1}$ for apple production (Taghavifar and Mardani 2015), 0.86 t $CO_{2eq} \cdot ha^{-1}$ for grape production (Mardani and Taghavifar 2016), 3.3 and 3.6 t $CO_{2eq} \cdot ha^{-1}$ for organic and conventional avocado orchards, respectively, in Mexico (Astier et al. 2014), 1.5, 1.6, 4.7, 3.1, 0.4, 1.8 and 2.3 t $CO_{2eq} \cdot ha^{-1}$ for Andean blackberry, avocado, Golden berry, lulo, mango, passion fruit and pineapple production, respectively, in Colombia (Graefe et al. 2013).

An average GHG emission for 1 t pomegranate production is 88.1 kg CO_2 in this study. The GHG emissions also range between 72.5–97.6 kg CO_2 per production of 1 ton pomegranate with respect to size groups (Table 4). This value was 1400 kg $CO_2 \cdot t^{-1}$ for corn (Yousefi et al. 2014), 263 kg $CO_2 \cdot t^{-1}$ for soybean (Knudsen et al. 2010), 303.4–467 kg $CO_2 \cdot t^{-1}$ for canola (Khojastehpour et al. 2015), 84.6 kg $CO_2 \cdot t^{-1}$ for tomato (Houshyar et al. 2015), 30–62 kg $CO_2 \cdot t^{-1}$ for potatoes (Gomiero et al. 2008).

Table 5 Econometric estimation results of energy production function

Inputs (Variables)[a]	Coefficient	t-value	*P*	MPP
Constant	6.349	2.175	0.034	–
Human labour	0.019	0.050	0.960	0.030
Machinery	–0.276	–1.456	0.151	–0.641
Diesel	–0.093	–2.011	0.049	–0.234
Chemical Fertilizer	0.236	2.196	0.032	0.402
Pesticides	1.010	2.668	0.010	2.451
Electricity	0.016	0.128	0.898	0.022
Land	0.124	0.282	0.779	3.259
F	77.013	–	0.000	–
R Square	0.901	–	–	–
Adjusted R Square	0.890	–	–	–
Durbin-Watson	1.902	–	–	–
Return to scale	1.036	–	–	–

[a]Dependent Variable: Energy production

Cobb-Douglass Energy Production Function Estimation

To investigate the relationship between the inputs and output, the Cobb-Douglas energy production function was estimated by using the physical inputs measures and pomegranate energy production per farm. The independent variables explained 90.1% of the variation in pomegranate energy production. The respective coefficients are provided in Table 5.

In this study presence of autocorrelation has been tested using the Durbin-Watson statistic test. Test results have revealed that, Durbin-Watson value is 1.90, indicating that there is no autocorrelation at the 1% significance level in the estimated model.

The estimated outcomes have revealed unexpected results; physical inputs of machinery and diesel use show negative effect on pomegranate energy production. These results are likely related to the excessive use of inputs. The intensive and excessive use of machinery and diesel can also be reason of low energy productivity. Consequently, machinery and diesel inputs should be used carefully by farmer to increase pomegranate energy productivity and efficiency in the research area.

Estimated coefficients except machinery and diesel indicate that the impact of inputs could be considered positively on pomegranate energy production. Human labour, farm electricity and land inputs coefficients were found statistically insignificant. The regression results have revealed that the contribution of pesticide is significant at the 1% level. Also, the impacts of chemical fertilizer and diesel are significant at 5% level. The estimated coefficients also indicate efficiency characteristics regarding production practices, and represent production elasticities. Therefore, the most important input in terms of production elasticity is pesticides (1.010), which mean an increase of 1% in pesticides usage, results in 1.010% energy production increase. The second important input has been found to be fertilizer with the elasticity of 0.236. The overall elasticity of inputs was close to unity (1.036), suggesting nearly constant return to scale relationship between the physical inputs and energy production.

The MPP value of the model variables is shown in the last column of Table 5. It can be seen that MPP of pomegranate land, pesticides, and chemicals fertilizer inputs have been found as 3.25, 2.45 and 0.40, respectively. These results indicate that last 1 unit of land, pesticides, and chemicals fertilizer used in pomegranate energy production provided 3.25, 2.45 and 0.40 MJ energy, respectively. The MPP values of machinery and diesel have been found negative, which indicates overuse of inputs.

Conclusions

This study reveals the quantities of energy inputs and outputs used in pomegranate production in Antalya. The data used in the study have been obtained through face-to-face interview with producers cultivating pomegranate in Antalya. In the study, energy input and energy output in pomegranate production are calculated to be 50,605.3 MJ · ha^{-1} and 76,252.3 MJ · ha^{-1}, respectively. Almost 63.7% of the energy inputs are chemical products as well as fertilizers and pesticides which are non-renewable in nature. Energy use efficiency and energy productivity ratios in the enterprises surveyed within the scope of the study are 1.51 and 0.39 kg · MJ^{-1}, respectively. Fertilizers, pesticides and electricity are major energy inputs in all size groups of farms. The results further reveals that small farms consume more input than others. Net energy output is highest in the largest group of farms. Moreover, energy inputs are being used more efficiently and productively in large farms in pomegranate production. Small size enterprises which are one of the most important problems of agricultural structure of Turkey also exist in pomegranate production.

In this study, CO_2 emission amounts are calculated to be 1.73 t CO_2 per hectare and 88.1 kg CO_2 per 1000 kg pomegranate production. Parallel to total energy input use, the CO_2 emission decreases as farm size increases, with the smallest amounts of CO_2 emission on large farms. Being a result of the study, increasing of the pomegranates orchards scales not only will increase energy efficiency and productivity but also decrease environmental pollution and damages. Furthermore, like the other agricultural crops productions, in pomegranate production the quantity of non-renewable energy input have been found higher, which arose particularly from chemical fertilizers, chemicals and equipment use. Principally, the conscious use of fertilizers and chemical inputs will ensure more efficient use of energy. According to the results of the energy production function estimation, machinery and diesel use showed negative impacts on energy production. These results are likely related to the excessive use of inputs. Consequently, machinery and diesel inputs should be used more carefully to increase energy productivity and efficiency in the research area. The variability in input use among pomegranate producing farmers was relatively high, determining the need to improve individual farm management abilities.

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Conflict of interest A. Ozalp, S. Yilmaz, C. Ertekin and I. Yilmaz declare that they have no competing interests.

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