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Review

An Investigation on the Energy Balance and Greenhouse Gas Emissions of Orange Production in Turkey

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Abstract: In agricultural production, it is important to determine where input usage saving can be implemented by taking energy use into consideration and to analyze the greenhouse gas emissions of agricultural activities. This study has been conducted to review orange (*Citrus sinensis* L.) production in terms of energy balance and greenhouse gas (GHG) emissions. This study was carried out during the 2015/2016 production season in Adana, a province in Turkey. Energy balance and GHG emissions have been defined by calculating the inputs and outputs of agricultural nature used in orange production. The findings of the study indicate that the distribution of energy inputs in orange production are 11,880 MJ ha^{-1} (34.10%) of electricity, 10,079.75 MJ ha^{-1} (28.93%) of chemical fertilizer energy, 7630 MJ ha^{-1} (21.90%) of chemical energy, 3052 MJ ha^{-1} (8.76%) of diesel fuel energy, 1348.91 MJ ha^{-1} (3.87%) of human labor energy, 378 MJ ha^{-1} (1.09%) of irrigation water energy, 351.22 MJ ha^{-1} (1.01%) of machinery energy and 118.80 MJ ha^{-1} (0.34%) of lime energy. In total, input energy (IE) in orange production has been calculated as 34,838.68 MJ ha^{-1} and the output energy (OE) has been calculated as 95,000 MJ ha^{-1}. Energy use efficiency (EUE), specific energy (SE), energy productivity (EP) and net energy (NE) have been calculated as 2.73, 0.70 MJ kg^{-1}, 1.44 kg MJ^{-1} and 60,161.32 MJ ha^{-1}, respectively. The total energy input in the production of oranges was divided into: 47.82% direct, 52.18% indirect, 4.96% from renewable sources and 95.04% from non-renewable sources. The GHG emissions figure for orange production was 3794.26 kg CO_{2-eq} ha^{-1}, with electricity having the greatest share, 1983.96 (52.29%); the GHG ratio was 0.08 kg CO_{2-eq} kg^{-1}. According to the results, the production of orange was considered to be profitable in terms of EUE.

Keywords: *Citrus sinensis* L.; energy input; energy output; energy use efficiency; GHG

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1. Introduction

Originally grown in China, Southeast Asia and India, citrus fruits are now grown in nearly every place with a subtropical climate. Citrus is a plant community that includes species such as chamomile, citron and bergamot, in addition to species such as goldentop, lemon, mandarin and orange, which are widely cultivated and have economic value. Citrus fruits include vitamin C and their health benefits are numerous. They are used to make jam, marmalade and fruit juice, are eaten fresh and used as raw materials in cosmetics [1]. The production of citrus species in the world takes place between 40° N latitude and 40° S latitude. The production of oranges (*Citrus sinensis* L.), one of the citrus species, is constantly increasing every year [2,3]. Among the most widely grown species, the orange accounts for more than half of the world's citrus production, with tangerine being the second most traded citrus fruit [4].

It is estimated that global production of oranges in the 2021/2022 season will increase by 1.4 million tons from the previous year and will total to 48.8 million in Brazil, Mexico and Turkey. In addition, it is projected that due to favorable weather conditions, the production of oranges in Turkey will increase by 40%, yielding 1.8 million tons. Moreover, it is stated that both the consumption of oranges and the export volume of this fruit have increased due to the increase in production in Turkey [5].

According to data from the Food and Agriculture Organization (FAO) of the United Nations on world orange production, Brazil is ranked in first place (31.8%), China is in second place (15.4%) and EU countries are in third place (12.3%). These countries are followed by the United States and Mexico [2,3]. Turkey is located at the upper northern border of the world's orange production areas. Orange is grown in over 140 countries around the world and Turkey ranks 7th in world production [2,3]. The production of citrus in Turkey dates back to 1936, with the first export taking place in 1950 [3,6]. In 1989, Turkey became a member of CLAM (Liaison Committee for Mediterranean Citrus), an organization of citrus fruits based in Madrid [3,7].

Burning fossil fuels causes GHG emissions, which absorb and emit radial energy inside the thermal infrared region. This results in the greenhouse effect, which consequently warms the Earth's surface. Water vapor, carbon oxide, nitrogen oxide, methane and ozone are among the main GHGs in the atmosphere. Fossil fuels are widely used as an energy source and are believed to be a major cause of global warming and atmospheric pollution. GHG emissions have serious and far-reaching consequences at local, regional, national and global levels [8]. Suffered at a global scale, the Coronavirus (COVID-19) pandemic led to the loss of many lives. The virus was so widespread that economic activities and large-scale production were halted in several nations during the year 2020. On the positive side, there was a significant reduction in carbon emissions following this stagnation [9,10].

Large amounts of greenhouse gas emissions from human activities, especially in the form of carbon dioxide (CO_2), and their consequences for climatic conditions, currently pose serious threats to the environment and to politics. In recent decades, GHG concentration in the atmosphere has risen immensely. The concentration of CO_2 increased from 280 ppm in 1700 to 380 ppm in 2006 [11,12]. Utilizing energy derived from fossil fuels leads to major concerns about the climate and air pollution. In addition, the non-renewable nature of fossil fuel energy makes it imperative to use it efficiently for future generations. There is a strong bond between levels of energy consumption and agriculture. Further to being a leading energy consumer, agriculture is also one of the important energy suppliers [12,13].

The adaptation of the agricultural applications' interpretation includes non-agricultural inputs or external inputs (i.e., carbon-based actions and products) [14,15]. The production, handling, formulation and storage of these inputs are made through mechanization. These, along with the burning of fossil fuels, lead to the emission of CO_2 or greenhouse gasses into the atmosphere. A kilogram of carbon equivalent (kg CE) is used to express the resulting emissions. This value should be defined for different uses such as harvesting, irrigation, pesticide application, fertilization and tillage, as well as alternatives to carbon such as renewable energy sources and biofuels for pest control, soil fertilization and other agricultural uses [15].

The most critical periods of fruit fall for citrus are the spring and early summer months. For citrus fruits that cannot get enough water during these periods, the leaves, with their stronger osmotic structures, take water from the fruits and cause them to fall. Accordingly, the importance of balanced and appropriate water application in the prevention of the excessive fall of flowers and fruit, as well as the energy requirement that occurs in this process, are revealed. Hatirli et al. [16] conducted a study on the agriculture-related energy use and concluded that such energy use is becoming more intense because the Green Revolution has led to an increase in the use of seeds, fertilizers and chemicals that are more productive. In addition, the use of diesel and electricity have also increased. The application of advanced technology, and the level of agricultural production, are proportional to the energy consumption per unit area. There are a number of inputs that correspond to a significant share of the total energy supply in the production system of modern agriculture. These inputs include fuel, machinery, fertilizers, electricity, seeds and chemicals. In modern times, inputs used in agriculture are more intense. Furthermore, energy derived from fossil fuels can be accessed easily. This has increased food production and living standards.

Economic development is highly dependent on energy use, as energy offers main utilities that sustain economic activity and increase the quality of human life. Underdeveloped countries are commonly suffering from energy shortages. However, it is believed that natural resources of energy are limitless. Nevertheless, before they can be used in agriculture, alternative energy sources must be carefully scrutinized for their ecologic impacts and potential threats to human health [17,18]. In production systems, energy inputs and outputs are analyzed, and such analyses generally aim to reveal the system's efficiency and environmental impacts [18–20]. Therefore, a system needs to be developed to compare the energy input versus the product output. This would make it possible to decrease the amount of greenhouse gases emissions in agricultural production [21,22].

Agriculture-related energy balance and GHG emissions have been studied numerous times. These studies were on the production of crops such as, for example, oranges [18,23,24], mandarins [24,25], lemons [26,27], pomegranates [28,29], kiwi [30,31], strawberry [32], grape [33], apples [34,35], pears [36,37], olive [38], peaches [39,40], corn [41], sunflower [42,43], potatoes [44], cotton [45] and vegetables [46,47]. This study has been conducted on the grounds that there are no extensive studies in the literature in relation to the energy use, energy-use efficiency indicators, greenhouse gas emissions and ratios of orange production on the study area. The province of Adana produces 318,990 tons of oranges, which corresponds to 18.31% of the total production (1,742,000 tons) in Turkey [48] and this potential is worth preparing an energy balance and GHG emission study.

2. Materials and Methods

The current study took place during the 2015/2016 production season in the Ceyhan District (Center/Mithatpaşa, Dokuztekne, İmran and Mustafabeyli) in Adana, Turkey. Adana is located in the Mediterranean region between the latitudes 35–38° N and the longitudes 34–46° E. It is surrounded by Kayseri to the north, Kahramanmaraş and Gaziantep to the east, Niğde and İçel to the west and Hatay to the southeast. Adana has a 160 km Mediterranean coastline in the south. The province covers an area of 17,253 km^2. The climate in Adana is under the influence of the Mediterranean region. The summer months are dry and warm, while the winter months are wet and mild. The level of rainfall in the region is usually formed by the encounter of slope rains and mobile air masses. The annual average amount of precipitation is 625 mm. It rains an average of 74 days a year. Although the average relative humidity is 66%, during the summer months, the level rises up to 90%. The average temperature over 37 years is 18.7 °C [49]. In 2021, various fruits were grown on an area of 53,139 decares in the Ceyhan district, and citrus was grown on an area of 17,017 decares in 13 Ceyhan neighborhoods. Oranges (*Citrus sinensis* L.) were grown on 1504 decares [50]. The soils in the study area have high lime, pH, clay and low organic matter content [51,52]. The average age of orange trees is 10. The study area is given in Figure 1.

Data utilized in this current study have been acquired through direct interviews with 45 different enterprises. These data have been compiled using a simple random sampling method, which has been proposed by Çiçek and Erkan [53], using Equation (1).

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

where:

n = required sample size;
N = total number of enterprises in the area;
s = standard deviation;

t = reliability coefficient (1.96 which represents, 95% confidence);
d = acceptable error (5% deviation).

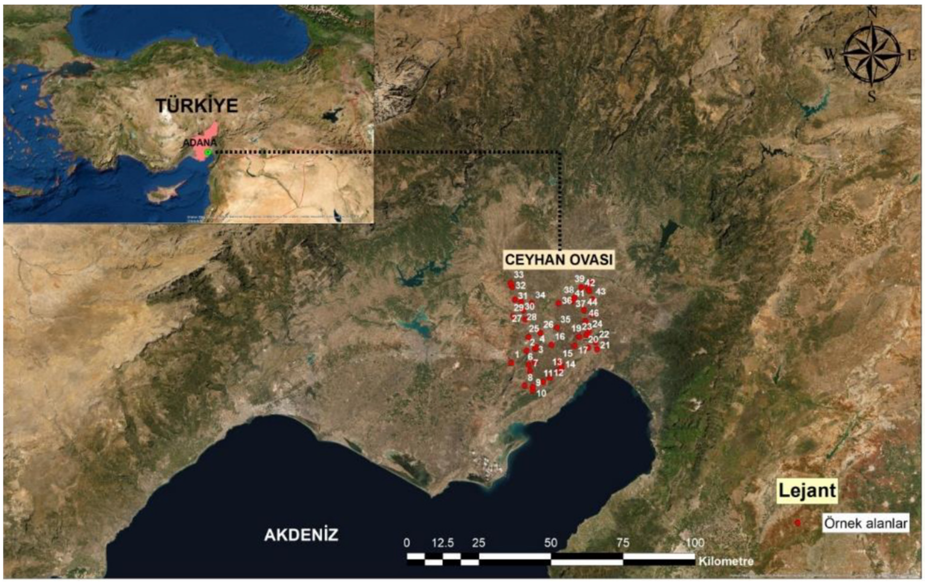

Figure 1. Location of the studied region in the Adana Province, Turkey [52].

Tables 1 and 2 have been utilized to analyze the energy equivalents of inputs and GHG equivalents in relation to orange production. In the study, human labor, chemical fertilizers, machinery energy, lime, chemicals, diesel fuel, electricity and irrigation water have been deemed as inputs, while orange fruit has been considered to be the output. Energy equivalents and the input per hectare of all inputs in units of MJ have been multiplied to acquire the total energy input. In order to investigate the energy balance in orange production, the EUE, SE, EP and NE have been acquired with the help of Equations (2)–(5) given below [30,54,55].

$$\text{Energy use efficiency} = \frac{\text{Energy output}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}, \tag{2}$$

$$\text{Specific energy} = \frac{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Orange fruit output}\left(\frac{\text{kg}}{\text{ha}}\right)}, \tag{3}$$

$$\text{Energy productivity} = \frac{\text{Orange fruit output}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Energy input}\left(\frac{\text{MJ}}{\text{ha}}\right)}, \tag{4}$$

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

The amount of greenhouse gas emission (kg $CO_{2\text{–eq}}$ ha^{-1}) corresponding to the inputs used to grow 1 ha of plant has been calculated by using Equation (6) [75,76].

$$\text{GHG}_{\text{ha}} = \sum_{i=1}^{n} \text{R(i)} \times \text{EF(i)}, \tag{6}$$

where:

R(i) = application ratio of input i (unit input ha^{-1});
EF(i) = greenhouse gas emission coefficient of input i (kg $CO_{2\text{–eq}}$ unit input^{-1}).

Moreover, an index was defined to assess the amount of kg CO_{2-eq} emitted per kg of yield, in accordance with the guidelines reported by Houshyar et al. [77] and Khoshnevisan et al. [32].

$$I_{GHG} = \frac{GHG_{ha}}{Y}, \tag{7}$$

where:

I_{GHG} = GHG ratio;
Y = yield as kg per ha.

Table 1. Energy equivalents in the production of oranges.

Inputs and Output	Unit	Energy Equivalent (MJ Unit^{-1})	References
		Inputs	
Human labor	h	1.96	[56,57]
Machinery	h	64.80	[21,58]
N	kg	60.60	[29,58]
P	kg	11.10	[29,54]
K	kg	6.70	[29,54]
S	kg	1.12	[30,59]
Herbicide	kg	418	[60,61]
Insecticide	kg	363.60	[60,61]
Fungicide	kg	310.60	[60,61]
Pesticides (general)	kg	199	[23,62]
Lime	kg	1.32	[26,60]
Electricity	kWh	3.60	[34,63]
Diesel fuel	L	56.31	[58,64]
Irrigation water	m^3	0.63	[65,66]
		Output	
Orange fruit	kg	1.90	[23,67]

Table 2. Greenhouse gas emissions coefficients in the production of oranges.

Inputs	Unit	GHG Equivalent (kg $CO_{2\text{-}eq}$ Unit^{-1})	References
Human labor	h	0.700	[68,69]
Machinery	MJ	0.071	[44,69]
N	kg	4.570	[69,70]
P	kg	1.180	[69,70]
K	kg	0.640	[69,70]
S	kg	0.370	[69,71]
Herbicide	kg	6.300	[29,72]
Insecticide	kg	5.100	[29,73]
Fungicide	kg	3.900	[29,72]
Chemicals	kg	13.900	[69,70]
Lime	kg	0.110	[69,74]
Electricity	MJ	0.167	[69,70]
Diesel fuel	L	2.760	[69,74]
Irrigation water	m^3	0.170	[69,73]

According to Koctürk and Engindeniz [78], input energy can be classified as direct and indirect, as well as renewable and non-renewable. Indirect energy (IDE) is associated with pesticides and fertilizers, while direct energy (DE) includes human and animal energy, diesel energy and electricity used for production. Non-renewable energy (NRE) consists of petrol, diesel, electricity, chemicals, fertilizers and machinery, whereas renewable energy (RE) consists of human and animal [54,79]. Tables 3–6 indicate energy use efficiency and energy balance calculations, energy input groups and greenhouse gas emissions related to orange production. The fertilizers used in the study consisted of ammonium sulfate, potassium sulfate and mono-ammonium-containing chemicals.

3. Results and Discussion

Based on the findings of the present study, the average amount of orange yield per hectare in the 2015/2016 production seasons was 50,000 kg per hectare (Table 3). Total input energy was calculated as 34,838.68 MJ ha^{-1} and the output energy (orange fruit) was calculated as 95,000 MJ ha^{-1}. The distribution of energy inputs in the production of oranges is presented in Figure 2.

Table 3. Energy balance in the production of orange fruits.

Inputs an Outputs	Unit	Energy Equivalent (MJ Unit^{-1})	Input Used Per Hectare (Unit ha^{-1})	Energy Value (MJ ha^{-1})	Ratio (%)
		Inputs			
Human labor	h	1.96	688.22	1348.91	3.87
Machinery	h	64.80	5.42	351.22	1.01
Chemical fertilizers	-	-	-	10,079.75	28.93
N	kg	60.60	141.45	8571.87	24.60
P	kg	11.10	73.20	812.52	2.33
K	kg	6.70	75.00	502.50	1.44
S	kg	1.12	172.20	192.86	0.55
Chemicals	-	-	-	7630.00	21.90
Herbicide	kg	418.00	6.00	2508.00	7.20
Insecticide	kg	363.60	8.00	2908.80	8.35
Fungicide	kg	310.60	2.00	621.20	1.78
Pesticides (general)	kg	199.00	8.00	1592.00	4.57
Lime	kg	1.32	90.00	118.80	0.34
Electricity	kWh	3.60	3300.00	11,880.00	34.10
Diesel fuel	l	56.31	54.20	3052.00	8.76
Irrigation water	m^3	0.63	600.00	378.00	1.09
Total inputs	-	-	-	34,838.68	100.00
		Outputs			
Orange fruit	kg	1.90	50,000.00	95,000.00	100.00
Total output	-	-	-	95,000.00	100.00

The orange yield obtained in the study area was calculated as 50,000 kg ha^{-1}. In other studies, the following orange yields were found: in the Antalya province, Turkey, by Ozkan et al. [23], 40,000 kg ha^{-1}; in Langroud, a town in the Guilan province, Iran, by Nabavi-Pelesaraei et al. [80], 27,800 kg ha^{-1}; and in the Ibadan Province, Nigeria, by Ogunlade et al. [81], 41,000 kg ha^{-1}, whereas Mohammadshirazi et al. [21] calculated it as 17,335.80 kg ha^{-1}. In comparison, the yields in mandarin and lemon production were calculated as 30,000 kg ha^{-1} and 35,000 kg ha^{-1}, respectively, in the Antalya province of Turkey by Ozkan et al. [23]. Finally, Loghmanpour Zarini et al. [18] calculated the yield in citrus production in the Mazandaran province of Iran as 15,454.54 kg ha^{-1}. The yield in the current study area is high compared to the above studies.

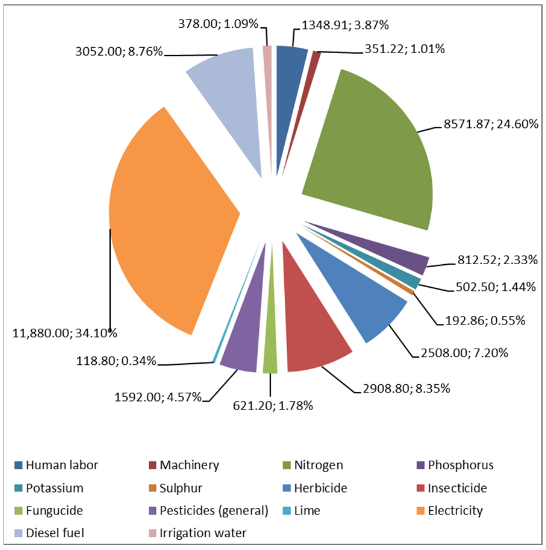

Figure 2. Distribution of energy inputs in the production of oranges.

Human labor used in the study was calculated as 1348.91 MJ ha^{-1} (3.87%). In previous studies on orange, human labor inputs were reported by Ozkan, et al. [23] as 1615.43 MJ ha^{-1} (2.65), by Ogunlade et al. [81] as 16,150.40 MJ ha^{-1} (34.63%) and Mohammadshirazi et al. [24] calculated it as 3869.7 MJ ha^{-1} (7.9%). The use of machine power per hectare in orange production in the study area was calculated as 351.22 MJ ha^{-1} (1.01%). Similarly, in previous studies, machine input was analyzed by Ozkan et al. [23] and reported as 787.51 MJ ha^{-1} (1.29), Ogunlade et al. [81] reported it as 732.97 MJ ha^{-1} (1.57%) and Mohammadshirazi et al. [24] reported it as 768.30 MJ ha^{-1} (1.6 %). According to the results of the study carried out on orange production, machine usage input is observed to be lower than human labor input.

Chemical fertilizer input has been calculated as 10,079.75 MJ ha^{-1} (28.93%) in the study. In previous studies, Ozkan et al. [23] reported that the share of chemical fertilizer energy used in the production of oranges is 44.42%. On the other hand, according to Loghmanpour Zarini et al. [18], the share of fertilizer energy in the production of oranges is 36.30%, and according to Mohammadshirazi et al. [24], this share is only 26.90%. Bilgili [26] reported that the share of fertilizer energy in the production of lemons is 47.96%, and according to Oğuz et al. [82] the share of fertilizer energy in the production of nectarines is 43.15%. According to Saltuk [47], in the production of tomatoes, the energy input for chemical fertilizers amounts to 33.39% (35,030 MJ ha^{-1}). The amount of chemical input is high both in the study area and in the above-mentioned studies.

Electricity use in the study has been calculated as 11,880 MJ ha^{-1} (34.10%). In previous studies on orange, Ozkan et al. [23] calculated electricity consumption input as 10,172.71 MJ ha^{-1} (16.69%), Ogunlade et al. [81] calculated it as 7401.97 MJ ha^{-1} (15.87%) and Mohammadshirazi et al. [24] calculated it as 4197 MJ ha^{-1} (8.6%). Orange production related water consumption per hectare in the study area has been calculated as 378 MJ ha^{-1} (1.09%). In previous studies, Mohammadshirazi et al. [24] calculated water consumption per hectare as 3013 MJ ha^{-1} (6.2%), Ozkan et al. [23] calculated it as 215.15 MJ ha^{-1} (0.35) and Ogunlade et al. [81] calculated it as 189.32 MJ ha^{-1} (0.41%).

In the current study on orange fruit, EI, EO, EUE, SE, EP and NE in orange production have been calculated as 50,000 kg ha^{-1}, 34,838.68 MJ ha^{-1}, 95,000 MJ ha^{-1}, 2.73, 0.70 MJ kg^{-1}, 1.44 kg MJ^{-1} and 60,161.32 MJ ha^{-1}, respectively (Table 4). In previous studies, the EUE calculated for orange production was 1.25 [23], 1.02 [18] or 1.84 [80]. For watermelon production, the EUE was 1.29 [83], and for grape production it was 6.57 [33]. According to the results of the current study and the results of the other studies examined above, it can be said that productions are profitable in terms of energy use efficiency.

Table 4. Calculations of the energy use efficiency in the production of oranges.

Calculations	Unit	Values
Orange fruit	kg ha^{-1}	50,000.00
EI	MJ ha^{-1}	34,838.68
EO	MJ ha^{-1}	95,000.00
EUE	-	2.73
SE	MJ kg^{-1}	0.70
EP	kg MJ^{-1}	1.44
NE	MJ ha^{-1}	60,161.32

In the study, the net energy was calculated as 60,161.32 MJ ha^{-1}. In previous studies on orange, Ozkan et al. [23] calculated the net energy as 15,050.31 MJ ha^{-1}, Ogunlade et al. [81] calculated it as 31,259.84 MJ ha^{-1} and Mohammadshirazi et al. [24] calculated it as −15,962.15 MJ ha^{-1}. Based on the reviewed study results, the outcome of the study conducted by Mohammadshirazi et al. [24] is negative, and therefore it is clear that the operation is not profitable in terms of energy use. In the current study, specific energy is the amount of energy required for the production of 1 kg of oranges, which has been calculated as 0.70 MJ^{-1} kg. In previous studies on orange, Ozkan et al. [23] calculated specific energy as 1.52 MJ^{-1} kg, Ogunlade et al. [81] calculated it as 1.13 MJ^{-1} kg and Mohammadshirazi et al. [24] calculated it as 2.82 MJ^{-1} kg.

The energy inputs for the production of oranges include direct, indirect, renewable and non-renewable energy. Table 5 shows the total energy input used in the production of oranges, which was 47.82% (16,658.91 MJ ha^{-1}) for DE, 52.18% (18,179.77 MJ ha^{-1}) for IDE, 4.96% (1726.91 MJ ha^{-1}) for RE energy and 95.04% (33,111.77 MJ ha^{-1}) for NRE energy. The share of NRE energy was greater than that of RE among energy inputs incurred in the production of oranges. Previous studies conducted on orange [18,23,24], apple [34], lemon [26], avocado [84] and kiwi [31], showed results in which the NRE ratio was also higher than the RE ratio. In order for the renewable energy rate to be higher than the non-renewable energy rate, it is important to reduce the chemical fertilizers, which have a significant place in the inputs. It is also important to increase the use of farm manure and organic fertilizers.

Table 5. Different energy groups of energy inputs in the production of oranges.

Energy Groups	Energy Input (MJ ha^{-1})	Ratio (%)
DE [1]	16,658.91	47.82
IDE [2]	18,179.77	52.18
Total	34,838.68	100.00
RE [3]	1726.91	4.96
NRE [4]	33,111.77	95.04
Total	34,838.68	100.00

[1] Includes human labor, diesel fuel, electricity and irrigation water; [2] Includes machinery, lime, chemical fertilizers and chemicals; [3] Includes human labor and irrigation water; [4] Includes machinery, lime, chemical fertilizers, diesel fuel, electricity and chemicals.

The results of GHGs for orange production are given in Table 6. The total for GHG emissions was 3794.26 kg $CO_{2\text{–eq}}$ ha^{-1} (3.79 ton $CO_{2\text{–eq}}$ ha^{-1}). The results of the study showed that electricity had the largest share of the total GHG emissions (1983.96 kg $CO_{2\text{–eq}}$ ha^{-1}) and that nitrogen (646.43 kg $CO_{2\text{–eq}}$ ha^{-1}) and human labor (481.75 kg $CO_{2\text{–eq}}$ ha^{-1}) were second and third, respectively. The GHG ratio (per kg) calculated in this study was 0.08. In previous studies, the total for GHG emissions for orange production was 0.75 ton $CO_{2\text{–eq}}$ ha^{-1} [80], 0.80 ton $CO_{2\text{–eq}}$ ha^{-1} [32] for strawberry production, 1.01 ton $CO_{2\text{–eq}}$ ha^{-1} [83] for watermelon production it was, 0.52 ton $CO_{2\text{–eq}}$ ha^{-1} [85] for kiwi production and 1.19 ton CO_{2-eq} ha^{-1} [86] for apple production. The distribution of GHGs in orange production is shown in Figure 3. Reducing the use of electricity, which has an important place in the study with a greenhouse gas emission rate of 52.29%, will also play an important role in reducing greenhouse gas emissions. For this, it is necessary to reduce the electricity used as a power source for orange production.

Table 6. Greenhouse gas emissions in the production of oranges.

Inputs	Unit	GHG Coefficient (kg CO_{2-eq} $Unit^{-1}$)	Input Used Per Area (Unit ha^{-1})	GHG Emissions (kg CO_{2-eq} ha^{-1})	Ratio (%)
Human labor	h	0.700	688.22	481.75	12.70
Machinery	MJ	0.071	351.22	24.94	0.66
N	kg	4.570	141.45	646.43	17.04
P	kg	1.180	73.20	86.38	2.28
K	kg	0.640	75.00	48.00	1.27
S	kg	0.370	172.20	63.71	1.68
Herbicide	kg	6.300	6.00	37.80	1.00
Insecticide	kg	5.100	8.00	40.80	1.08
Fungicide	kg	3.900	2.00	7.80	0.21
Pesticides (general)	kg	13.900	8.00	111.20	2.93
Lime	kg	0.110	90.00	9.90	0.26
Electricity	MJ	0.167	11880	1983.96	52.29
Diesel fuel	L	2.760	54.20	149.59	3.94
Irrigation water	m^3	0.170	600.00	102.00	2.69
Total	-	-	-	3794.26	100.00
GHG ration (per kg)	-	-	-	0.08	-

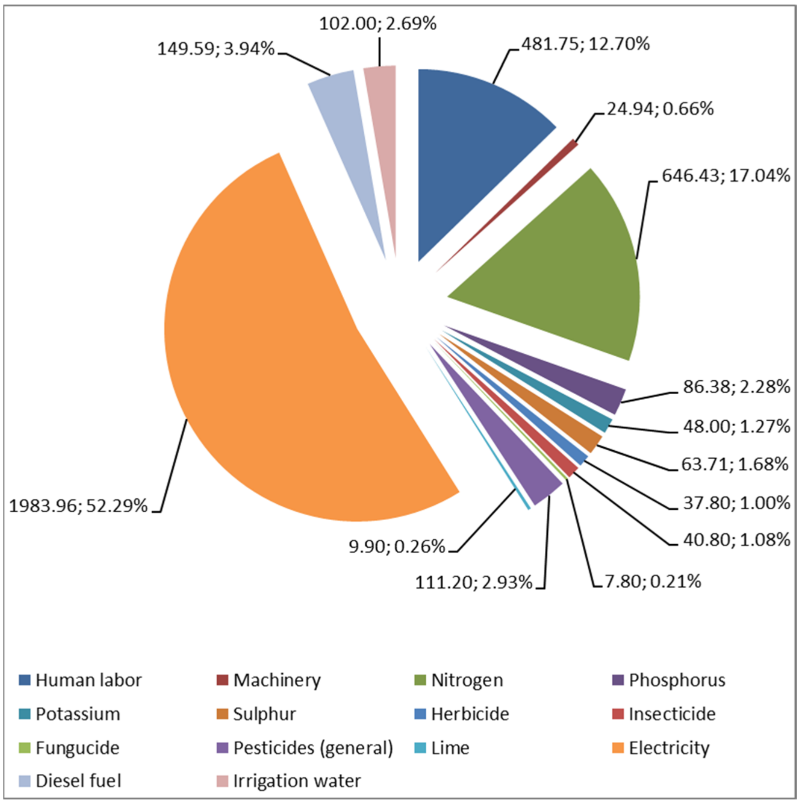

Figure 3. Distribution of greenhouse gas emissions in orange production (kg CO_{2-eq} ha^{-1}; %).

4. Conclusions

This study analyzed energy balance and greenhouse gas emissions. The EI and EO in the production of oranges have been calculated as 34,838.68 MJ ha^{-1} and 95,000 MJ ha^{-1}, respectively. The biggest source of energy consumption was electricity (34.10%) followed by chemical fertilizer energy (28.93%) and chemical energy (21.90%). EUE, SE, EP and NE amounted to 2.73, 0.70 MJ kg^{-1}, 1.44 kg MJ^{-1} and 60,161.32 MJ ha^{-1}, respectively. According to the results, the production of oranges was considered to be profitable in terms of EUE.

The total energy inputs used in the production of oranges are grouped as direct 47.82%, indirect 52.18%, renewable 4.96% and non-renewable 95.04%. The consumption of chemical fertilizers has greatly in energy use. The total for GHG emissions has been calculated as 3794.26 kg CO_{2-eq} ha^{-1} (3.79 ton CO_{2-eq} ha^{-1}). The findings indicate that the share of electricity was the largest (1983.96 kg CO_{2-eq} ha^{-1}) among GHG emissions and the GHG ratio (per kg) was at the level of 0.08.

The conclusion of this study is that new methods of producing oranges should be adopted to reduce the consumption of chemical fertilizers and electricity. Achieving proper energy management in the production of oranges would be possible with the introduction of such new methods. According to Nabavi-Pelesaraei et al. [83], it is necessary to use plant, soil and climate pollution analyses in order to specify the required soil fertilizers, which should reduce the high chemical fertilizer energy consumption and GHG emissions.

Performing soil analysis for a more efficient, timely and accurate application of nitrogen chemical fertilizers, and by reducing the amount of nitrogen chemical fertilizers used by replacing them with alternatives in biological ways such as using bio-fertilizers, natural and green manures, can improve energy efficiency and mitigate GHG emissions in production [87]. According to Mohammadi-Barsari [87], power tillers and outdated tractors can be renewed, which would reduce excessive fuel consumption. Similarly, using a conservation tillage system can also save fuel while contributing to higher energy efficiency and lower GHG emissions per unit production in rain-fed production. These views apply to the discoveries presented in this paper.

The current study dwells on the energy balance and greenhouse gas (GHG) emissions related to orange production in Turkey. It is important to address this interesting and topical issue. GHG emission is directly responsible for the harms caused on nature, and solutions such as new methods in agricultural practice, including new crop production methods, are promising as they contribute to improving energy efficiency and reducing GHG emissions. Therefore, the research findings have important scientific and practical implications.

The increased amounts of greenhouse gas and CO_2 emissions related to food safety, agricultural practices and soil and environmental degradation in the early 2000s led to increasingly harmful effects caused by greenhouse gases. Conversion of tillage with plow to no-tillage, adaptation of integrated nitrogen management and pest control practices, drip irrigation and underground irrigation methods will lead to an improvement in water use and controlling carbon emissions [15].

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