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RESEARCH

# Energy Use Efficiency and Greenhouse Gas Emissions in Sour Cherry (*Prunus cerasus L.*) Production Systems in Türkiye

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**Abstract**
The purpose of this study was to establish whether sour cherry (Prunus cerasus L.) production is a sustainable practice through determining the energy use and greenhouse gas (GHG) emissions produced by the process. Data for the study were collected using personal interviews with thirty-nine (39) farmers who grow sour cherries. The total amount of energy used (total energy input) and energy produced (total energy output) were found to be 13,652.01 MJ/ha$^{-1}$ and 43,906.43 MJ/ha$^{-1}$, respectively. The energy use efficiency of the sour cherry production system was determined to be 3.26; the specific energy use were 0.94 MJ/kg; the energy productivity was 1.11 kg/MJ; and the net energy use was 30,254.42 MJ/ha. The direct energy use and indirect energy use of the sour cherry production system were determined to be 45.72% and 54.28%, respectively; and the renewable and non-renewable energy use were determined to be 5.18% and 94.82%, respectively. The total amount of GHG emissions associated with the sour cherry production system was estimated to be 1367.81 kg CO2-eq/ha, and the emission intensity of the sour cherry production system was estimated to be 0.09 kg CO2-eq/kg. The fertilizer use was the largest contributor to both the total amount of energy used in the sour cherry production system and the total GHG emissions of the sour cherry production system. Overall, the results of this study demonstrate that sour cherry production systems are operating beyond the energy break-even point; however, they are also reliant upon non-renewable inputs. Therefore, improving the fertilizer use efficiency and encouraging the use of renewable energy sources will improve both the environmental and economic sustainability of sour cherry cultivation.

**Keywords** Energy use efficiency · Net energy · Specific energy · Renewable energy · Greenhouse gas emissions · Sour cherry

## Introduction

The use of energy by contemporary agricultural systems is one of the major factors that will influence the long-term health of an economy and the total environmental impacts caused by these systems. The increasing costs associated with energy, the continued dependence upon fossil fuel sources, and the increasing necessity to reduce greenhouse gas (GHG) emissions caused by the burning of fossil fuels for energy have created a world-wide imperative to rationalize the management of agricultural energy resources. While agriculture accounts for about four percent of global energy use, the “indirect” contribution to GHG emissions from agriculture is significantly larger than that percentage due to its heavy reliance on fossil-based input materials, i.e., petroleum products, fertilizers and electricity (Helsel 1992; Fluck and Baird 1982). Because of this, it is becoming more and more important that agricultural producers use energy in their operations as efficiently as possible while simulta-

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neously reducing the environmental footprint of agricultural production.

Compared to other sectors of agriculture, fruit production is particularly significant to study because of the relative high level of resource intensity involved with the process of producing fruit. For example, many of the processes involved with fruit production (irrigation, fertilization, mechanical operations, harvesting, etc.) are relatively high-energy consuming and therefore result in a lot of GHG emissions on a per acre basis (Mohammadi et al. 2010; Houshyar et al. 2015; Yaldız et al. 1993). Many governments and international organizations have studied the amount of energy required to grow various types of fruits (including but not limited to) apricots (Gezer et al. 2003; Gündoğmuş 2006), apples (Taghavifar and Mardani 2015; Rafiee et al. 2010), cherries (Aydın and Aktürk 2018), pomegranates (Troujeni et al. 2018; Akcaoz et al. 2009; Baran and Kadak 2025), walnuts (Candemir et al. 2024), kiwis (Nabavi-Pelesaraei et al. 2016; Gökdoğan 2022), cumin (Yilmaz et al. 2021), oranges (Saltuk et al. 2022), lemons (Özbek et al. 2023), avocados (Gökduman et al. 2022), winegrapes (Güner and Candemir 2026), grapes (Ağızan et al. 2024; Baran et al. 2017), vetch (Kokten et al. 2017), sunflower (Baran et al. 2016), cotton (Gokdogan et al. 2016), peach (Demir and Gökdoğan 2023), garlic (Baran et al. 2023), cherry (Gökdoğan et al. 2024), pistachio (Gökdoğan et al. 2022) and almonds (Baran et al. 2020). Most of the total energy used to grow those fruits came from nonrenewable resources (fertilizers, electricity and diesel) while most of the remaining portion came from renewable resources (manure and human labor). In addition, Houshyar et al. (2015), Troujeni et al. (2018), and Sarı and Gökdoğan (2024) stated that excessive energy use by farmers will generally lead to increased amounts of greenhouse gas emissions, primarily through the use of electricity and nitrate-based fertilizers.Due to its various agroecological regions and large area available for cultivation, Türkiye is at a strategic point within the world's fruit production. Additionally, according to FAOStat (2022), Türkiye is ranked third globally in terms of the total amount of cherries, apricots and sour cherries produced. Sour cherry (Prunus cerasus L.) is a highly valuable commercially grown fruit with respect to its high utilization potential through both home consumption and export, and its ability to be used in various forms of food processing (Altın 2006; Öktem 2018). Nevertheless, the large amounts of electrical power utilized by the current production system and the widespread use of synthetic chemical fertilizers contribute to increased carbon intensity and reduced energy efficiency (Gökduman et al. 2022).

Over the last several years, the importance of energy management in agriculture was seen as both economically significant as well as an important metric of environmental sustainability (Mohammadi et al. 2010; Eren et al. 2019). An important way that farmers have been able to reduce their dependence on fossil fuels while at the same time reducing greenhouse gas emissions is through using renewable energy technologies such as solar power for irrigation systems and biomass energy for heating systems (Maraseni et al. 2010; Graefe et al. 2013). Most prior research however focused on selected crops with limited consideration of regional production patterns or the variations within each system (Eren et al. 2019).

The purpose of this research project is to investigate the energy consumption levels and indicators of energy use efficiencies and GHG emissions of sour cherry production systems in Türkiye. This will be accomplished by combining energy input/output models with assessments of renewable versus nonrenewable energy sources used in the production processes. The aim of this research is to develop an objective quantification of the environmental impacts associated with sour cherry production systems and to identify opportunities for improvements in energy use and emissions reductions. It is anticipated that the data collected from this research project can be used to support the development of optimized and reduced emission management practices for sour cherry producers as part of the larger effort to create environmentally sustainable agricultural production systems.

## Materıal and Method

The Konya Province (See Fig. 1) has been the focus area of this study which is considered one of the largest fruit producing areas in Türkiye. The Konya Region's climate is classified as a Continental Climate and includes extremely hot and dry summer months and very cold and harsh winter months. As a result of the water shortage problem in the region, sour cherry growing activities are mostly located in those areas where there is an easy access to water sources.

In order to collect data related to all the input parameters involved in the production activities such as Labor, Machinery, Fuel, Electricity, Chemical Fertilizers, Livestock Manure, Pesticides, Irrigation and Transportation and Production Yield, a comprehensive Questionnaire was prepared. Producers were selected according to Purposeful Sampling Method (Newbold 1995).

$$n = \frac{Np\,(1-p)}{(N-1)\,\sigma_{px}^{2} + p\,(1-p)}$$

The number of participants ($n$) in this study provided the sample size; the value of $p$ (the proportion of people who have a particular characteristic) provided the proportion of people with a specific characteristic; and the value of q (the complement) provided 1–$p$ (i.e., one minus $p$). Because $p$ is

**Fig. 1** Study Area's Map

usually an unknown value, it should therefore be assumed to be equal to 0.5 to achieve the largest possible sample size. The margin of error (d) was computed using the equation d = (percentage error mean); the t-value associated with the confidence interval will depend on whether the sample size is either greater than 39 or less than/equal to 39. It was determined that conducting surveys with at least 39 farmers/producers would be sufficient as per the criteria used for establishing the minimum sample size requirement for the survey. A survey was conducted in the village of Ereğli, mainly in areas of high sour cherry production.

The energy inputs involved in sour cherry production were found by multiplying the quantity of each input used in the sour cherry production process with the appropriate energy equivalent factor. The energy equivalent factors listed in Table 1 were based on the standard conversion factors documented in Singh (2002), Mandal et al. (2002), and Ozkan et al. (2004). The energy equivalents for human labor, machinery, fuel, fertilizer, irrigation water, and electricity were determined separately and summed to provide the overall energy input for the sour cherry production process.

The GHG emissions related to sour cherry production were estimated using energy-based emission coefficients. These coefficients, listed in Table 2, follow the emission coefficients reported by Lal (2004), Dyer and Desjardins (2006), and Khoshnevisan et al. (2014). Each energy component was multiplied by its respective emission coefficient so that both direct (from fuel, electricity and water) and indirect (from fertilizers, machinery and pesticides) emissions could be accounted for collectively.

Energy use efficiency indicators were calculated according to the formulations developed by Mandal et al. (2002) and Singh et al. (1997). Therefore, the energy use efficiency (EUE), energy productivity (EP), specific energy (SE), and net energy (NE) were calculated using the following equations:

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

$$\text{Specific energy} = \frac{\text{Energy input}\ \left(\text{MJ ha}^{-1}\right)}{\text{Yield output}\ \left(\text{kg ha}^{-1}\right)} \tag{2}$$

$$\text{Energy productivity} = \frac{\text{Yield output}\ \left(\text{kg ha}^{-1}\right)}{\text{Energy input}\ \left(\text{MJ ha}^{-1}\right)} \tag{3}$$

$$\begin{gathered}\text{Net energy} = \\ \text{Energy output}\,(\text{MJ ha}^{-1}) - \text{Energy input}\,(\text{MJ ha}^{-1})\end{gathered} \tag{4}$$

To determine the total Greenhouse Gas Emissions (in kg $CO_{2\text{-eq}}/ha^{-1}$) for the production of 1 ha of Sour Cherry, Hughes et al. (2011) developed a methodology that is based on the summation of the products of each input's application rate, denoted as R(i), and its respective Greenhouse Gas Emission Coefficient, denoted as EF(i). To calculate the total Greenhouse Gas Emissions per unit weight of Sour Cherry produced (in kg $CO_{2\text{-eq}}/kg^{-1}$), an Index has been de-

**Table 1** Standard coefficients to compute energy content of outputs and inputs in sour cherry production

| **Inputs** | **Unit** | **Energy equivalent (MJ unit$^{-1}$)** | **References** |
|---|---|---|---|
| Labour | H | 1.96 | Mani et al. (2007); Karaağaç et al. (2011) |
| *Machinery* | | | |
| Tractor | H | 62.7 | Singh et al. (2002) |
| Plough | H | 18.7 | Singh et al. (2002) |
| *Pesticides* | | | |
| Insecticides | Kg | 278 | Rafiee et al. (2010) |
| Fungicides | Kg | 216 | Rafiee et al. (2010) |
| *Organic fertilizers* | | | |
| Farmyard manure | Kg | 0.30 | Singh et al. (2002) |
| *Chemical fertilizers* | | | |
| Nitrogen | Kg | 60.60 | Singh (2002); Ozalp et al. (2018) |
| Phosphorus | Kg | 11.10 | Mandal et al. (2002); Candemir et al. (2024) |
| Potassium | Kg | 6.70 | Mandal et al. (2002) |
| *Others* | | | |
| Diesel | L | 56.31 | Singh et al. (2002); Bayramoğlu et al. (2025) |
| Irrigation water | m$^3$ | 1.02 | Acaroglu (1998); Azizi and Heidari (2013) |
| Electricity | kWh | 3.60 | Ozkan et al. (2004) |
| Transportation | MJ.t.km | 4.5 | Fluck and Baird (1982); Kitani (1999) |
| **Output** | **Unit** | **Energy equivalent (MJ unit$^{-1}$)** | **Reference** |
| Sour Cherry | Kg | 2.93 | Vahid-Berimanlou and Nadi (2021) |

**Table 2** GHG emissions coefficients in production

| Inputs | Unit | GHG equivalent (kg$CO_{2\text{-eq}}$ unit$^{-1}$) | References |
|---|---|---|---|
| Labour | H | 0.700 | Houshyar et al. (2015) |
| Machinery | MJ | 0.071 | Pishgar-Komleh et al. (2012); Eren et al. (2019) |
| Farmyard manure | Ton | 0.029 | Meisterling et al. (2009) |
| Insecticides | Kg | 3.931 | Graefe et al. (2013) |
| Fungicide | Kg | 3.900 | Graefe et al. (2013) |
| Nitrogen | Kg | 1.300 | Lal (2004); Candemir et al. (2025) |
| Phosphorus | Kg | 0.200 | Lal (2004); Ozalp et al. (2018) |
| Potassium | Kg | 0.200 | Taghavifar and Mardani (2015) |
| Diesel | L | 2.760 | Dyer and Desjardins (2006); Ozalp et al. (2018) |
| Electricity | kWh | 0.608 | Khoshnevisan et al. (2014) |
| Transportation | Kg | 0.150 | Meisterling et al. (2009); Eren et al. (2019) |

veloped which is denoted as $I_{GHG} = \sum(EF(i)R(i))/Y$; where Y represents the yield of Sour Cherry (in kg/ha); (Eren et al. 2019).

$$GHG_{ha} = \sum_{i=1}^{n} R(i)\,x\,EF(i) \tag{5}$$

$$I_{GHG} = \frac{GHG_{ha}}{Y} \tag{6}$$

## Discussion

Total energy input was 13,652.01 MJ/ha$^{-1}$ and total energy output was 43,906.43 MJ/ha$^{-1}$. Nitrogen fertilizer was the largest contributor at 35.20%, followed by electricity at 34.86%, and then farmyard manure at 8.68%. These percentages are consistent with Sarı and Gökdoğan (2024), who stated that in sour cherry production in Isparta, the largest contributions were from diesel (47.26%), chemical fertilizers (26.03%), and human labor (10.77%). Therefore, the data suggest a significant dependency on non-renewable energy sources. The percentage of electricity is also

**Table 3** EUE in sour cherry production

| Inputs | Unit | Energy equivalent (MJ unit$^{-1}$) | Input used per hectare (unit ha$^{-1}$) | Energy value (MJ ha$^{-1}$) | Ratio (%) |
|---|---|---|---|---|---|
| *Labor* | – | – | *360.78* | 707.13 | 5.18 |
| Pruning | H | 1.96 | 54.62 | 107.05 | 0.78 |
| Soil tillage (2 times) | H | 1.96 | 3.43 | 6.73 | 0.05 |
| Fertilizing (Chemical and Farmyard) | H | 1.96 | 15.34 | 30.07 | 0.22 |
| Spraying | H | 1.96 | 1.92 | 3.77 | 0.03 |
| Irrigation | H | 1.96 | 84.29 | 165.22 | 1.21 |
| Harvesting | H | 1.96 | 200.18 | 392.35 | 2.87 |
| Transportation | H | 1.96 | 1.00 | 1.95 | 0.01 |
| *Machinery* | – | – | – | 543.71 | 3.98 |
| Tractor | H | 62.7 | 7.65 | 479.54 | 3.51 |
| Plough (2 times) | H | 18.7 | 3.43 | 64.17 | 0.47 |
| *Pesticides* | – | – | – | 596.57 | 4.37 |
| Fungusit | Kg | 216 | 1.14 | 245.35 | 1.80 |
| İnsektisit | Kg | 278 | 1.26 | 351.21 | 2.57 |
| *Farmyard Manure* | – | 0.3 | 3948.72 | 1184.62 | 8.68 |
| *Chemical Fertilizers* | – | – | – | 5081.32 | 37.22 |
| Nitrogen | Kg | 60.6 | 79.31 | 4805.94 | 35.20 |
| Phosphorus | Kg | 11.1 | 24.81 | 275.38 | 2.02 |
| *Diesel* | L | 56.31 | 13.76 | 774.56 | 5.67 |
| *Electricity* | kWh | 3.6 | 1322.12 | 4759.62 | 34.86 |
| *Transportation* | Mj.t.km | 4.5 | 1.00 | 4.48 | 0.03 |
| *Total Input* | – | – | – | 13.652.01 | 100.00 |
| **Output** | **Unit** | **Energy equivalent (MJ/unit)** | **Output per hectare (unit ha$^{-1}$)** | **Energy value (MJ ha$^{-1}$)** | **Ratio (%)** |
| Soul Cherry fruit | Kg | *2.93* | 14,985 | 43,906.43 | *100.00* |
| Total output | – | – | – | 43,906.43 | 100.00 |

similar to Baran and Gökdoğan (2022), who determined that electricity contributed to 34.06% of the total energy consumption for cotton. Chemical fertilizers comprised 37.22% of the energy consumption, which is relatively close to the 42% reported by Kızılaslan (2009) for cherry. However, the percentage of energy coming from farmyard manure (8.68%) is substantially less than the 33.32% reported by Karakayacı (2024) for organic aronia production; therefore, it appears there is an underutilization of renewable energy inputs in sour cherry systems. Furthermore, these results support those of Özbek et al. (2023) regarding lemon production, in which electricity comprised 17.73% and nitrogen-related emissions comprised 35.86% of the total greenhouse gas (GHG) emissions. Collectively, the results demonstrate that diesel, fertilizer, and electricity continue to be the primary drivers of energy consumption, thereby representing the most significant barriers to improving energy efficiency—results that have been consistently echoed by Vahid-Berimanlou and Nadi (2021), Gökduman et al. (2022), and Sarı and Gökdoğan (2024).

The energy composition as shown in Table 3 illustrates that sour cherry production is still very much reliant upon fossil based and chemical energy sources. As a whole, nearly 70% of the energy used in the entire system is accounted for by electricity and nitrogen fertilizers which demonstrates that sour cherry production's energy utilization is not yet optimized nor sustainable. However, the relatively small but positive input of farm yard manure does illustrate the opportunities for renewable energy use in the system and that there are opportunities to increase this share of energy if appropriate strategies to manage this type of renewable input were to be implemented. These findings demonstrate the need to rebalance the types of energy being utilized in sour cherry production (notably replacing fossil based electricity with renewable energy sources and decreasing reliance upon chemical fertilizers) to reduce environmental impacts associated with sour cherry production while enhancing the long term energy efficiency of the production process (Table 4).

Energy use efficiency (EUE) in sour cherry cultivation was 3.26, which shows that the total energy produced (43,906.43 MJ ha$^{-1}$) is about 3 times the total energy used (13,652.01 MJ ha$^{-1}$). This EUE value is greater than those reported by Baran et al. (2020) for almond production

**Table 4** EUE calculations in sour cherry production

| Calculations | Unit | Values |
|---|---|---|
| Sour Cherry Fruit | kg ha$^{-1}$ | 14,985.13 |
| EI | MJ ha$^{-1}$ | 13,652.01 |
| EO | MJ ha$^{-1}$ | 43,906.43 |
| EUE | – | 3.22 |
| SE | MJ kg$^{-1}$ | 0.91 |
| EP | kg MJ$^{-1}$ | 1.09 |
| NE | MJ ha$^{-1}$ | 30,254.42 |

**Table 5** Energy inputs in the varieties of energy for sour cherry production

| Energy groups | Energy input (MJ ha$^{-1}$) | Ratio (%) |
|---|---|---|
| DE | 6241.31 | 45.72 |
| IDE | 7410.70 | 54.28 |
| *Total* | *13,652.01* | *100.00* |
| RE | 707.13 | 5.18 |
| NRE | 12,944.87 | 94.82 |
| *Total* | *13,652.01* | *100.00* |

(2.85) and by Gökduman et al. (2022) for avocado production (2.63) and nearly equivalent to the 3.24 value of Özbek et al. (2023) for lemon production; this suggests that sour cherry production has an equal or possibly better energy efficiency ratio and a favorable relationship between yield and input use compared to other fruit crops. In comparison, pomegranate production had lower EUE values of 2.45 (Akcaoz et al. 2009), 2.52 (Çanakçı 2010), 2.38 (Houshyar et al. 2015) and 2.60 (Özalp et al. 2018); therefore, sour cherry production has a more energy efficient process of using inputs to produce outputs. Sour cherry production had a SE of 0.94 MJ kg$^{-1}$, EP of 1.11 kg MJ$^{-1}$, and NE of 30,254.42 MJ ha$^{-1}$. All of these energy indicators are less than the ranges reported by Namdari et al. (2011) and Saltuk et al. (2022) for citrus production, showing a reduction in energy use per kilogram of fruit. The results also support the conclusions of Bilgili (2012) and Söyler et al. (2022) that there is a relationship between the balanced use of inputs and the highest NE. Overall, the results indicate that sour cherry production is one of the most energy efficient fruit systems and that optimization of both electricity and nitrogen fertilizer will allow for further improvement in net energy gain and environmental sustainability (Table 5).

Sour cherry production uses a lot of different types of energy. The majority of the 45.72% of the energy used is from direct energy and indirect energy inputs. Both of these are almost the same percent as they were in pomegranate (Akcaoz et al. 2009) at 69.21% and 72.26% for lemon (Özbek et al. 2023). Direct energy includes the amount of energy needed to create chemical fertilizers and pesticides, as well as the electricity needed for irrigation pumps etc. Indirect energy represents all other forms of energy that go into growing sour cherries. The percentage of renewable energy (RE) used in the production of sour cherries is 5.18%. Non-renewable energy (NRE) made up 94.82% of the energy used in the production of sour cherries. All three of these percentages are much lower than those found in the study of pomegranate (Akcaoz et al. 2009) which has a renewable energy (RE) percent of 12.57% and a non-renewable energy (NRE) percent of 87.43%. Those values to produce lemons also show low levels of renewable energy (RE) at 8.55%, but higher values for non-renewable energy (NRE) at 91.45% (Özbek et al. 2023). Organic aronia production had a significantly high level of renewable energy (RE) at 52.66%. This shows how using organic methods in farming can dramatically improve the energy balance of sour cherry production. Thus, there will be significant potential for improvement in the energy sustainability of sour cherry production if producers increase their use of renewable in-

**Table 6** GHG emissions in sour cherry production

| Inputs | Unit | GHG coefficient (kg $CO_{2eq}$ unit$^{-1}$) | Input used per area (unit ha$^{-1}$) | GHG emissions (kg $CO_{2eq}$ ha$^{-1}$) | Ratio (%) |
|---|---|---|---|---|---|
| Labor | H | 0.700 | 360.78 | 252.55 | 18.46 |
| Machinery | MJ | 0.071 | 543.71 | 38.60 | 2.82 |
| Farmyard manure | Ton | 0.029 | 3948.72 | 114.51 | 8.37 |
| Fungucides | Kg | 6.300 | 1.14 | 7.16 | 0.52 |
| Insecticides | Kg | 3.931 | 1.26 | 4.97 | 0.36 |
| Nitrogen | Kg | 1.300 | 79.31 | 103.10 | 7.54 |
| Phosphorus | Kg | 0.200 | 24.81 | 4.96 | 0.36 |
| Diesel | L | 2.760 | 13.76 | 37.96 | 2.78 |
| Electricity | kWh | 0.608 | 1322.12 | 803.85 | 58.77 |
| Transportation | kg | 0.150 | 1 | 0.15 | 0.01 |
| Total | – | – | – | 1367.81 | 100.00 |
| GHG ratio (per kg) | – | – | – | 0.09 | – |

puts (such as manure from their farms), reduce their use of chemical fertilizers, and switch their electric energy use to renewable energy sources (Table 6).

Electricity was the greatest GHG contributor (58.77%) in sour cherry production at 1367.81 kg $CO_2$-eq $ha^{-1}$. In sour cherry production, electricity was the largest source of GHG emissions, like that found in lemon production; irrigation and electricity also were the largest GHG contributors in lemon production (Özbek et al. 2023). Diesel generated 2.78% of total GHG emissions; this percentage was significantly less than the 68% reported in sour cherry production using traditional practices and demonstrates improved efficiencies in mechanical processes and decreased reliance on petroleum-based energy. Nitrogen fertilizer was responsible for 7.54% of total GHG emissions; this is significantly lower than the 28.83% reported in pomegranate production (Akcaoz et al. 2009); thus, the current nutrient application strategies are more well-balanced in terms of nutrient availability. With an emission intensity of 0.09 kg $CO_2$-eq/kg, sour cherry production has a moderate carbon impact when compared to other fruits, such as cherry (0.19 kg $CO_2$-eq/kg) and lemon (0.08 kg $CO_2$-eq/kg) production. The 8.37% share from the farmyard manure indicates that there may be opportunities to increase the utilization of renewable inputs to continue to decrease the carbon footprint associated with sour cherry production. By optimizing both electricity and nitrogen fertilizer use along with developing renewable-based irrigation systems, the carbon footprint associated with sour cherry production could be greatly decreased.

## Conclusion

The study examined the quantitative relationship between energy use, energy efficiency and greenhouse gas (GHG) emissions in the production of sour cherries. Energy positive sour cherry production is indicated through the data that show the total energy produced during the production process of sour cherries is about three times larger than the total amount of energy required to produce them. A significant portion of indirect energy input into sour cherry production is from nonrenewable sources; most notably from the use of chemical fertilizers and electricity. Electricity consumption has been found to be the major component of GHG emissions generated during the entire sour cherry production process. Nitrogen fertilizers and labor are the next greatest contributors to GHG emissions. Due to the small volume of diesel used and the balanced fertilizer application, the overall level of GHG emissions remains moderate. Sour cherry production has a product-based emission intensity of 0.09 kg CO2-eq/kg which indicates a relatively low to medium carbon load compared to many other fruit production systems. The data suggests there are three major ways to improve energy sustainability in sour cherry production: (i) transition the electrical energy consumed to renewable energy sources, (ii) reduce the amount of chemical fertilizer applied while increasing the proportion of renewable inputs, such as manure from livestock, and (iii) adopt an integrated approach to manage all forms of energy. Improving energy sustainability in sour cherry production can help to reduce environmental impacts as well as increase energy efficiency, ultimately allowing sour cherry producers to create more environmentally friendly and climate resilient agricultural systems.

**Conflict of interest** S. Candemir, M. Bozdemir Akçil, H.G. Doğan and Z. Bayramoğlu declare that they have no competing interests.

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