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Research Article

Determining the Energy Use Efficiency and Greenhouse Gas Emissions (GHG) in Olive Farming

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Abstract

In this research, energy use efficiency and GHG ratio computations were determined in olive farming. It was practiced in Çakallık area of Karpuzlu district of Aydın province of Turkey. Experiments and research datas computations were based on the January 2020 - January 2021 growing season. Energy input (EI) and energy output (EO) in olive farming were computed as 2580.70 MJ ha^{-1} and 9904.04 MJ ha^{-1}. In olive farming, 46.96% of all energy inputs consists of nitrogen energy (1212 MJ ha^{-1}), 25.49% consists of human labour energy (657.88 MJ ha^{-1}), 8.60% consists of phosphorus energy (222 MJ ha^{-1}), 8.04% consists of electricity energy (207.36 MJ ha^{-1}), 5.19% consists of potassium energy (134 MJ ha^{-1}), 5.14% consists of transportation energy (132.53 MJ ha^{-1}) and 0.58% consists of sulphur energy (14.93 MJ ha^{-1}). Energy use efficiency (EUE), specific energy (SE), energy productivity (EP) and net energy (NE) in olive farming were computed as 3.84, 0.88 MJ kg^{-1}, 1.14 kg MJ^{-1} and 7323.34 MJ ha^{-1}, respectively. Energy inputs in olive farming could be classified as 33.53% direct, 66.47% indirect, 25.49% renewable and 74.51% non-renewable. Total GHG emissions were computed as 406.73 kg$CO_{2\text{-}eq}$ha^{-1} for olive farming with the greatest input being use of human labour (57.77%). Human labour input is followed by nitrogen (22.47%), electricity (8.51%), phosphorus (5.80%), potassium (3.15%), sulphur (1.21%) and transportation inputs (1.09%), respectively. GHG ratio value was computed as 0.14 kg$CO_{2\text{-}eq}$kg^{-1} in olive farming.

Key words: Olive, Energy productivity, GHG emissions, Aydın.

Zeytin Yetiştiriciliğinde Enerji Kullanım Etkinliğinin ve Sera Gazı (GHG) Emisyonunun Belirlenmesi

Öz

Bu araştırmada zeytin yetiştiriciliğinde enerji kullanım etkinliliği ve sera gazı oranı belirlenmiştir. Araştırma, Türkiye'nin Aydın ili Karpuzlu ilçesine bağlı Çakallık mevkiinde yapılmıştır. Denemeler ve araştırma verileri hesaplamaları Ocak 2020 - Ocak 2021 yetiştirme sezonuna dayanmaktadır. Zeytin yetiştiriciliğinde enerji girdisi ve çıktısı sırasıyla 2580.70 MJ ha^{-1}, 9904.04 MJ ha^{-1} olarak hesaplanmıştır. Zeytin yetiştiriciliğinde tüm enerji girdilerinin %46.96'sı azot enerjisinden (1212 MJ ha^{-1}), %25.49'u insan işgücü enerjisinden (657.88 MJ ha^{-1}), %8.60'ı fosfor enerjisinden (222 MJ ha^{-1}), %8.04'ü elektrik enerjisinden (207.36 MJ ha^{-1}), %5.19'u potasyum enerjisinden (134 MJ ha^{-1}),%5.14'ü taşıma enerjisinden (132.53 MJ ha^{-1}) ve % 0.58'i kükürt enerjisinden (14.93 MJ ha^{-1}) oluşmaktadır. Zeytin yetiştiriciliğinde enerji kullanım etkinliği, spesifik enerji, enerji verimliliği ve net enerji sırasıyla 3.84, 0.88 MJ kg^{-1}, 1.14 kg MJ^{-1} ve 7323.34 MJ ha^{-1} olarak hesaplanmıştır. Zeytin yetiştiriciliğinde enerji girdisinin %33.53'ü doğrudan, %66.47'si dolaylı, %25.49'u yenilenebilir ve %74.51'i yenilenemez olarak sınıflandırılabilir. Zeytin yetiştiriciliği için toplam sera gazı emisyonları 406.73 kg$CO_{2\text{-}eş}$ha^{-1} olarak hesaplanmıştır ve en büyük girdi insan işgücü kullanımıdır (%57.77). İnsan işgücü girdisini sırasıyla azot (%22.47), elektrik (%8.51), fosfor (%5.80), potasyum (%3.15), kükürt (%1.21) ve taşıma girdileri (%1.09) takip etmektedir. Ayrıca zeytin yetiştiriciliğinde sera gazı oranı değeri 0.14 kg$CO_{2\text{-}eş}$ha^{-1} olarak hesaplanmıştır.

Anahtar Kelimeler: Zeytin, Enerji verimliliği, Sera gazı emisyonu, Aydın.

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1. Introduction

Table olive has been around almost as long as the history of mankind, dating back to the early Bronze Age (3150 to 1200 BCE). Olive has been traced to the eastern Mediterranean Coastline, encompassing what is southern Turkey, Syria, Lebanon, Palestine, and Israel now. The origin has been traced through written tablets, olive pits, and wood fragments found in ancient tombs (Vossen, 2007). Despite being rich in phenolic compounds, only 2% of the total phenolic content of olive fruit actually goes through in the oil-extraction phase. Majority is lost during the water phase (approx. 53%) and along with the solid pomace residue (approx. 45%; round 2-8 g polyphenols/kg depending on processing) (Rodis et al., 2012; Criminna et al., 2016). The total olive growing areas worldwide amount to approximately 10 million hectares. In Turkey, olive growing areas are mostly concentrated in the Aegean and Mediterranean Regions and it has had the tendency to increase over the years. The most prominent provinces in terms of olive growing areas in Turkey are Aydın, Muğla and İzmir. According to TÜİK (Turkish Statistical Institute) Crop Production Statistics, the total olive production in 2019 was 1.5 million tons and around 75% of this production consisted of oil olive (Anonymous, 2020).

The rate of fossil fuel use in energy generation is growing higher by each day and this not only leads to the depletion of a significant resource but also poses intimidating threats for the future. The use of renewable sources must be encouraged for energy production and it is also highly important to reduce energy consumption. A good starting point to achieve these could be by ensuring energy efficiency during production processes. In this sense, the amount of energy used for each stage of production must be clearly identified so that consumption levels could be reduced and/or alternative means could be established. Acting so can help to have less issue in supply, price instability and environmental harm. The quality of an energy source can be analysed in various ways, and one of these is called net energy analysis. This method of analysis compares the energy obtained from a given resource and the one required, whether direct and indirect, and makes it available to the end-user (Herendeen, 2004; Cleveland, 2014a; Cleveland, 2014b; Cappelletti et al., 2014).

Energy balance is an significant determiner that shows the efficiency of production methods and compares them (Hacıseferoğulları et al., 2003). Energy analysis related to agricultural production is a significant approach in defining and gathering farming systems in terms of energy utilization. It is necessary to carefully analyse the inputs and outputs used in production to increase efficiency and decrease inputs in production (Sabah, 2010; Karaağaç et al., 2019). However, more intensive energy use causes significant environmental problems that both affect human health and lead to GHG emissions. Therefore, efficient use of inputs is very significant in terms of sustainable agricultural production. GHG in agricultural production arise due to the use of machinery, diesel fuel consumption, chemical fertilizer use and electricity consumption, and without a doubt, GHG also increase with the increase in energy input (Karaağaç et al., 2019).

A number of previous studies were accomplished on EUE in agriculture and animal production. Such studies include those on EUE and GHG emissions of olive (Guzmán and Alonso, 2008; Hemmati et al., 2013; Gökdoğan and Erdoğan, 2018), cherry (Demircan et al., 2006; Kizilaslan, 2009; Aydın and Aktürk, 2018); peach (Göktolga et al., 2006; Gündoğmuş, 2014; Aydın and Aktürk, 2018), pomegranate (Akcaoz et al., 2009; Canakci 2010; Ozalp et al., 2018), citrus (Ozkan et al., 2004a; Qasemi-Kordkheili and Rabhar, 2015; Yilmaz and Aydin, 2020), drybean (Sonmete and Demir, 2007; Ertekin et al., 2010; Kazemi et al., 2015), groundnut (Baran et al., 2018; Saltuk, 2019), wheat (Tipi et al., 2009; Çiçek et al., 2011, Unakıtan and Aydın, 2018), sunflower (Bayhan, 2016; Akdemir et al., 2017; Unakıtan and Aydın, 2018), corn (Konak et al., 2004; Öztürk et al., 2008; Barut et al., 2011), onion (Arın and Akdemir, 1987; Ozbek et al., 2021), poultry (Atılgan and Köknaroğlu, 2006; Demircan and Köknaroğlu, 2007; Saltuk et al., 2020) etc. The aim of this research is to review the EUE and GHG emissions of olive farming in Aydın province.

2. Material and Method

Aydın is a province where activities in agriculture, tourism, domestic and foreign trade and industry are conducted and it is located in the western part of Aegean Region and is in the middle of the triangle that consists of Eastern Europe, Middle Asia and Middle East. Its coordinates are 37. and 38. north latitude and 27. and 29. east longitudes in southwestern Turkey. The total area of the province is 811600 ha, and as of 2017, approximately 45% (366608 ha) of the total area is cultivated. It is surrounded by the Aegean Sea in the west, Denizli province in the east, İzmir and Manisa provinces in the north and Muğla province in the south. Maquis vegetation is dominant in Aydın. Olive, fig and chestnut grows naturally in the environment. The main climate of the province is Mediterranean climate. Annual average precipitation is 645.1 mm and no notable differences are observed between sub-regions. Most of the annual precipitation falls during the winter months. 51.45% of the average precipitation falls in winter, 24.79% falls in spring, 21.61% falls in autumn and 3.04% falls in summer. With regards to average temperatures extending to years, the lowest temperature was observed as 8.2 °C in January, while the highest temperature 28.4 °C was observed in July. Average relative humidity is around 61.2% (Anonymous, 2018).

This current study was conducted during the January 2020 - January 2021 growing season in Çakallık locality of Karpuzlu district of Aydın province of Turkey. Experiments and research datas computations are related to the January 2020 - January 2021 growing season. The research was done in a 3 da (0.3 ha) area, by using randomized complete block design with three replications. Area work productivity was determined as effective area work productivity. Effective work duration (t_{ef}) was used to compute the work productivity (ha h^{-1}) (Özcan, 1986; Güzel, 1986; Sonmete, 2006). A chronometer was used to measure the durations in the research (Sonmete, 2006).

Total energy use was determined by computing the agricultural input energy and output energy used in olive farming. Human labour energy, nitrogen energy, phosphorus energy, potassium energy, sulphur energy, electricity energy and transportation energy were considered as inputs. Energy coefficients of the inputs and output used in olive farming were shown in Table 1. EUE, SE, EP and NE were computed by using the below shown formulas (Mandal et al., 2002; Mohammadi et al., 2008; Mohammadi et al., 2010). Energy inputs could be classified as direct, indirect, renewable and non-renewable (Mandal et al., 2002; Singh et al., 2003; Koçtürk and Engindeniz, 2009). GHG emission coefficients of inputs in olive farming were shown in Table 2. In olive farming, direct, indirect, renewable and non-renewable classifications of energy balance, EUE computations and energy inputs types were shown in Table 3, Table 4 and Table 5.

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

$$\text{Specific energy} = \frac{\text{Energy input }(\frac{\text{MJ}}{\text{ha}})}{\text{Product output }(\frac{\text{kg}}{\text{ha}})} \quad (2)$$

$$\text{Energy productivity} = \frac{\text{Product output }(\frac{\text{kg}}{\text{ha}})}{\text{Energy input }(\frac{\text{MJ}}{\text{ha}})} \quad (3)$$

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

Eren et al. (2019) reported that; "The (GHG) emissions ($kgCO_{2\text{-}eq}ha^{-1}$) associated with the inputs to grow 1 ha of plant were calculated by using the following formula adapted by Hughes et al. (2011). Where R(i) is the application rate of input i ($unit_{input}ha^{-1}$) and EF(i) is the GHG emission coefficient of input i ($kgCO_{2\text{-}eq}unit_{input}^{-1}$). Moreover, an index is defined to evaluate the amount of emitted $kgCO_{2\text{-}eq}$ per kg yield as follows as adapted by Khoshnevisan et al. (2014) and Houshyar et al. (2015). Where I_{GHG} is GHG ratio and Y is the yield as kg per ha".

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

$$I_{GHG} = \frac{GHG_{ha}}{Y} \quad (6)$$

Table 1. Energy coefficients of inputs and outputs in olive farming

Inputs	**Unit (br)**	**Energy coefficient (MJ unit^{-1})**	**References**
Human labour	h	1.96	Mani et al., 2007; Karaağaç et al., 2011
Nitrogen	kg	60.60	Singh, 2002
Phosphorous	kg	11.10	Singh, 2002
Potassium	kg	6.70	Singh, 2002
Sulphur	kg	1.12	Nagy, 1999; Mohammadi et al., 2010
Electricity	kWh	3.60	Ozkan et al., 2004b
Transportation	MJ (ton km)$^{-1}$	4.50	Fluck and Baird, 1982; Kitani, 1999
Output (Yield)	kg	11.80	Ozkan et al., 2004c

*Table 2. GHG emissions coefficients in olive farming**

Inputs	Unit (br)	GHG coefficients (kg $CO_{2\text{-}eq}$ unit^{-1})	References
Human labour	h	0.700	Nguyen and Hermansen, 2012
Nitrogen	kg	4.570	BioGrace-II, 2015
Phosphorous	kg	1.180	BioGrace-II, 2015
Potassium	kg	0.640	BioGrace-II, 2015
Sulphur	kg	0.370	Maraseni et al. (2010)
Electricity	MJ	0.167	BioGrace-II, 2015
Transportation	ton . km	0.150	Meisterling et al., 2009

*: Adapted from Eren et al. (2019)

3. Results and Discussion

During the current research, conducted in January 2020 - January 2021 growing season, an average of 2945 kg ha^{-1} olive was yielded. According to Table 3, energy input in olive farming was computed as 2580.70 MJ ha^{-1} and energy output was computed as 9904.04 MJ ha^{-1}. In olive farming, 1212 MJ ha^{-1} of the energy inputs consisted of nitrogen energy (46.96%), 657.88 MJ ha^{-1} human labour energy (25.49%), 222 MJ ha^{-1} phosphorus energy (8.60%), 207.36 MJ ha^{-1} electricity energy (8.04%), 134 MJ ha^{-1} potassium energy (5.19%), 132.53 MJ ha^{-1} transportation energy (5.14%) and 14.93 MJ ha^{-1} sulphur energy (0.58%).

In this research conducted in olive farming, human labour activities consisted of soil tillage, fertilizing, pruning and olive-picking. Tillage was done with human labour using a hoe and shovel. Pruning operation was done by using handsaw. Olive shaking process was done with an electrically charged olive shaking machine. Nitrogen, phosphorous, potassium and sulphur were used as fertilizers.

EUE, SE, EP and NE were computed as 3.84, 0.88 MJ kg^{-1}, 1.14 kg MJ^{-1} and 7323.34 MJ ha^{-1}, respectively (Table 4). In previous researches; Kizilaslan (2009) determined an EUE of 0.96 in cherry production, Hemmati et al. (2013) determined an EUE of 1.24 in olive farming, while Gökdoğan and Erdoğan (2018) determined an EUE of 2.72 in olive farming.

The used total energy inputs in olive farming could be classified as 33.53% direct, 66.47% indirect, 25.49% renewable and 74.51% non-renewable (Table 5). In olive farming, 25.49% of the total energy inputs consisted of renewable energy while 74.51% consisted of non-renewable energy consumption (Table 5). Similar to the findings of previous researches on pomegranate (Akcaoz et al., 2009), black carrot (Çelik et al., 2010), avocado (Astier et al., 2014), the results determined a higher ratio of non-renewable energy than the ratio of renewable energy. According to Tan (2018), it is advisable to raise the amount of renewable energy in energy use.

The results of GHG emissions of olive farming were shown in Table 6. Total GHG emissions were computed as 406.73 kg$CO_{2\text{-}eq}$ha^{-1} for olive farming with a human labour use of 234.96 kg$CO_{2\text{-}eq}$ha^{-1} (57.77%), which was the greatest input. The human labour use was followed up by nitrogen use by 91.40 kg$CO_{2\text{-}eq}$ha^{-1} (22.47%), electricity by 34.63 kg$CO_{2\text{-}eq}$ha^{-1} (8.51%), phosphorous use by 23.60 kg$CO_{2\text{-}eq}$ha^{-1} (5.80%), potassium use by 12.80 kg$CO_{2\text{-}eq}$ha^{-1} (3.15%), sulphur by 4.93 kg$CO_{2\text{-}eq}$ha^{-1} (1.21%) and transportation by 4.42 kg$CO_{2\text{-}eq}$ha^{-1} (1.09%). In previous researches, Nabavi-Pelesaraei et al. (2016) computed the total GHG emission of kiwi fruit production as 1310 kg$CO_{2\text{-}eq}$ha^{-1}; Mohammadi-Barsari et al. (2016) computed the total GHG emission of watermelon production as 460.41 kg$CO_{2\text{-}eq}$ha^{-1}; Ozalp et al. (2018) computed the total GHG emission of pomegranate production as 1730 kg$CO_{2\text{-}eq}$ha^{-1}.

Table 3. Energy balance in olive farming

Inputs	**Unit (br)**	**Energy coefficient (MJ unit^{-1})**	**Input used per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Ratio (%)**
Human labour	h	1.96	335.65	657.88	25.49
-Soil tillage	h	1.96	101.33	198.60	7.70
-Fertilizing	h	1.96	31.66	62.06	2.40
-Pruning	h	1.96	50.66	99.30	3.85
-Harvesting	h	1.96	152	297.92	11.54
Nitrogen	kg	60.60	20	1212.00	46.96
Phosphorous	kg	11.10	20	222.00	8.60
Potassium	kg	6.70	20	134.00	5.19
Sulphur	kg	1.12	13.33	14.93	0.58
Electricity	kWh	3.6	57.60	207.36	8.04
Transportation	MJ (ton km)$^{-1}$	4.50	2.945*10*	132.53	5.14
Total				2580.70	100.00
Output	**Unit (br)**	**Energy equivalent (MJ unit^{-1})**	**Yield per hectare (unit ha^{-1})**	**Energy value (MJ ha^{-1})**	**Ratio (%)**
Yield	kg	11.80	2945	9904.04	100.00

*: Transportation distance is 10 km (Average).

Table 4. Computations of EUE in olive farming

Computations	**Unit**	**Values**
Yield	kg ha^{-1}	2945
EI	MJ ha^{-1}	2580.70
EO	MJ ha^{-1}	9904.04
EUE		3.84
SE	MJ kg^{-1}	0.88
EP	kg MJ^{-1}	1.14
NE	MJ ha^{-1}	7323.34

Table 5. Energy inputs types in olive farming

Energy types	**EI (MJ ha^{-1})**	**Ratio (%)**
Direct energy	865.24	33.53
Indirect energy	1715.45	66.47
Total	2580.70	100.00
Renewable energy	657.88	25.49
Non-renewable energy	1922.81	74.51
Total	2580.70	100.00

Table 6. GHG emissions coefficients in olive farming

Inputs	**Unit (br)**	**GHG Coefficient (kg CO_{2eq} unit^{-1})**	**Input used per area (unit ha^{-1})**	**GHG emissions (kgCO_{2-eq}ha^{-1})**	**Ratio (%)**
Human labour	h	0.700	335.65	234.96	57.77
Nitrogen	kg	4.570	20.00	91.40	22.47
Phosphorous	kg	1.180	20.00	23.60	5.80
Potassium	kg	0.640	20.00	12.80	3.15
Sulphur	kg	0.370	13.33	4.93	1.21
Electricity	MJ	0.167	207.36	34.63	8.51
Transportation	ton . km	0.150	29.45	4.42	1.09
Total				406.73	100.00
GHG ratio (per kg)				0.14	

4. Conclusions and Recommendations

Based on this research the following conclusions were determined.

-During the research, an average of 2945 kg ha^{-1} olive has been yielded during the January 2020 - January 2021 growing season. Olive farming used a total energy of 2580.70 MJ ha^{-1}, which was the highest due to a nitrogen use of 1212 MJ ha^{-1} (46.96%). The energy inputs of human labour by 657.88 MJ ha^{-1} (25.49%) and phosphorous by 222 MJ ha^{-1} (8.60%) were the second and third greatest values in total energy inputs.

-EUE, SE, EP and NE were determined as 3.84, 0.88 MJ kg^{-1}, 1.14 kg MJ^{-1} and 7323.34 MJ ha^{-1}.

-Direct energy, indirect energy, renewable and non-renewable energy inputs were determined as 33.53%, 66.47%, 25.49% and 74.51% of the total energy inputs, respectively.

-Total GHG emissions were determined as 406.73 $kgCO_{2\text{-}eq}ha^{-1}$ for olive farming with the greatest part including of human labour use by 234.96 $kgCO_{2\text{-}eq}ha^{-1}$ (57.77%). The human labour was followed by nitrogen use by 91.40 $kgCO_{2\text{-}eq}ha^{-1}$ (22.47%), electricity use by 34.63 $kgCO_{2\text{-}eq}ha^{-1}$ (8.51%) in second and third places among the total GHG emissions.

-In this research, the energy utilization of olive farming was determined. As the results, olive farming is an economic type of production in terms of EUE (3.84) for January 2020 - January 2021 growing season.

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