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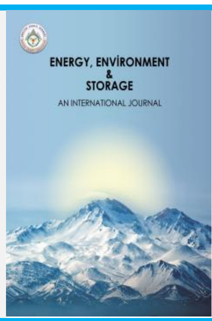

A Comparison of Energy Use in Conventional and Organic Olive Production in Kaz Mountains, Çanakkale, Türkiye

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ABSTRACT. Agriculture is one of the biggest sectors and energy consumption during agricultural production causes a release of 11 % of greenhouse gasses leading to climate change. Since after the industrialization of agriculture, farming systems shifted towards high-intensity farming, yet in Türkiye, traditional farming methods continue. In this study we compare the energy efficiency of organic vs. conventional olive groves in Kaz Mountains, Türkiye. 71 farmers were interviewed face-to-face in two subsequent years and the energy efficiency of the olive production process was calculated as the ratio of the energy spent during farming to the energy content of the fruit. Fuel use was calculated under the direct energy input, whereas production processes of fertilizer, agricultural machinery, maintenance and repair, human and animal labor were calculated under indirect energy inputs. Here we show that conventional olive production was less energy efficient due to the high indirect energy input during the production of synthetic fertilizers. There was no relationship between the energy input and yield. This study shows that by improving energy efficiency, the technical performance of agricultural systems can be increased and their negative impact on the environment can be reduced.

Keywords: Olive Production, Energy Efficiency, Energy Consumption, Organic Farming, Conventional Farming

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1. INTRODUCTION

Olive production in Türkiye has developed rapidly since 1937. Traditional olive production generally involves building stone terraces along slopes in shallow fertile soil type [1] where main energy is human and animal power with lack of chemical input. Although profound changes have been made in the practices in olive groves while low-density systems are replaced by high-density farms [2], in Türkiye many olive groves continue produce olive with traditional farming methods while adding the use of synthetic fertilizers and pesticides, a very broad farming method defined as conventional farming. Yet, due to the environmental impacts of pesticide use in conventional farming, and with the increase of awareness among farmers and consumers, organic farming, an agricultural method where synthetic inputs are banned, has gained more importance. The demand for products produced by organic methods has gradually increased and organic product markets have developed rapidly [3].

Conventional and organic farming have differences in applications, one of the most prominent differences is the ban of synthetic chemical use in organic farming. Yet, except this difference there also are many similarities such as the use of fossil fuel, agricultural machinery, irrigation methods. Mechanization is one factor increasing the energy demand and use and due to this fact energy consumption in the agricultural sector is increasing rapidly [4]. Energy consumption in turn, causes environmental problems such as global warming, air pollution, acid rain and ozone depletion [5]. To ensure a sustainable development in the agricultural sector, it is essential to increase energy efficiency and as the concept of sustainable development gains more and more importance, the efforts towards energy efficiency are also becoming important. For this purpose, improving energy efficiency during all stages, preventing waste, reducing energy loss both on sectoral and macro level are among the priority actions [4]. If energy efficiency can be improved, the technical performance of the agricultural system will increase, while the damage to the environment will be reduced. Increasing energy efficiency will contribute economically to producers as well as reducing environmental impacts [6].

Many studies have been carried out in different countries on the energy efficiency of olive groves. The energy

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efficiency of olive groves in Greece [3, 7, 8], Italy [9, 10], Spain [11], Morocco and Portugal [12] were previously studied. In Türkiye, the research in this area is very limited. Hence it is important to compare different production methods and determine the most suitable methods to reduce energy use without causing a decrease in the yield in order to reduce the negative effects of agriculture on the environment.

This study concentrates on olive farms to compare the energy efficiency and yield between conventional and organic olive groves in Kaz Mountains, Çanakkale, Türkiye. Two questions were answered "Which farming type uses more energy, organic or conventional?" and "Which farming type is more energy efficient?". This paper also tries to answer if small adjustments in each farming methods can be made to decrease the environmental impacts and increase the energy efficiency of olive production.

2. MATERIALS AND METHODS

2.1 Study Area

One of the leading regions in olive cultivation in Turkey is the Marmara Region, where Türkiye realizes 18% of its total olive production [13, 14]. In Çanakkale, 9.6% of the agricultural lands are covered with olive groves and Turkey meets 7.3% of its olive production from Çanakkale [15]. Olive groves are more concentrated in the coastal parts of Ayvacık and Ezine districts. About 1,734,000 of the 4,107,000 olive trees in the province belong to Ayvacık districts [16].

The study was carried out in olive groves in Kaz Mountains, north of Edremit Bay, between Balıkesir and Çanakkale provinces in the Marmara Region (Fig. 1). Kaz Mountains are located between 26°15′-26°35′ east longitudes and 39°30′-39°50′ north latitudes. The region is surrounded by Ayvacık and Ezine provinces in the west, Bayramiç and Çan in the north, Kalkım, Yenice and Balya in the east, and Edremit and Havran in the south [17].

Fig. 1. The study area (Red color: Organic farms, blue: conventional farms, green: natural areas).

The olive groves are located both on slope and flat areas and the climate has both the characteristics of the Central Anatolia and the Mediterranean Regions [17]. While the annual precipitation ranges between 579.1 mm and 844.3 mm, the annual average relative humidity varies between 60% and 74%, and the annual average temperature between 12.8 ℃ and 13.2 ℃ [18].

2.2 Aim and Scope

The aim of this study is to determine if energy efficiency differs between conventional and organic olive production systems in Kaz Mountains. agricultural activities will be recommended.

Two different olive groves, organic and conventional, were studied in Kaz Mountains. Fig. 2 shows the system boundaries of organic and conventional olive groves. In organic areas, it is allowed to use burgundy slurry (a mixture of copper (II) sulfate and slaked lime) authorized by the EU to combat fungal disease on olive trees.

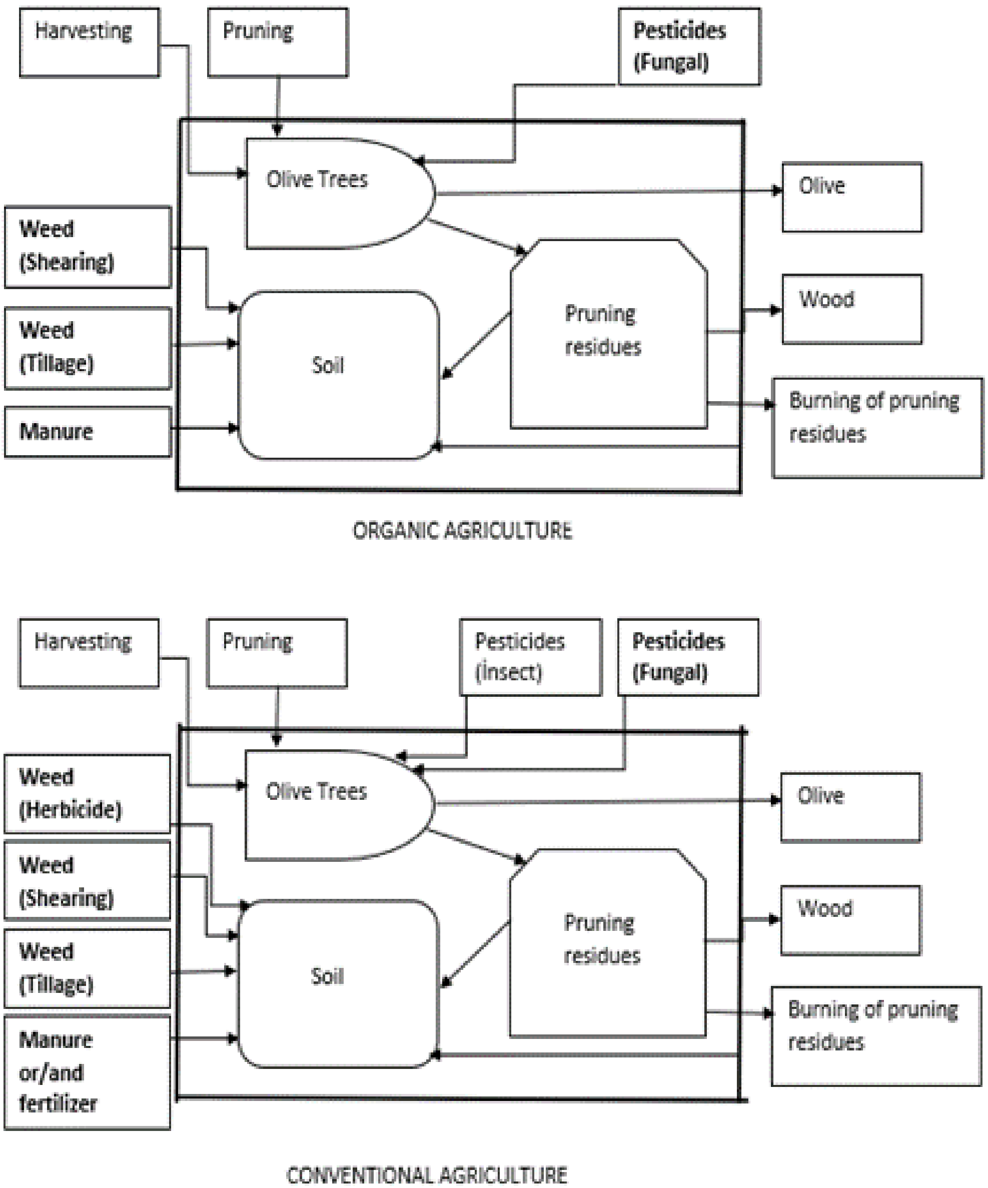


Fig. 2. System boundaries of organic and conventional olive groves. (Applications written in bold are the most frequently used applications.)

The data for the years 2015 and 2016 used in this study were taken from the project data titled 'Determination of Biodiversity Friendly Agricultural Activities in Olive Groves in Kaz Mountains'-.To be able to properly represent the production metods of the local region, GIS methods were applied. First by using ArcGIS, organic olive production sites with a size of 6 ha and above were selected and the conventional farms with similar topographic features were later included to the study [19]. In two subsequent years (2015 and 2016), face-to-face interviews were organized. In 2015, farmers from 27 organic parcels and 37 conventional parcels participated while in 2016, farmers from 24 organic parcels and 32 conventional parcels participated. The farmers were asked of their production methods, tools, inputs, and outputs throughout these two growing seasons.

The farmers were evaluated in two categories in the study: (1) Producers who carry out organic certified olive growing activities and those who have adopted organic production although they do not have a certificate, (2) Conventional producers. The farms were monitored regularly for biodiversity studies and pesticide and herbicide analyses were carried out at the end of the project. Farmers who do not follow strictly organic production protocols were removed from the organic farmers group.

2.3 Energy Efficiency in Agricultural System

Providing a global view of the efficiency of the farm process, energy analysis is an ideal method for addressing agriculture in a sustainable way [3]. To obtain the farm inputs, all the energy spent from the extraction of raw materials to the final product is calculated. This analysis also shows the socio-economic aspects of the agricultural process, as energy from fossil fuels can in some cases be replaced by human labor. The equation of energy efficiency is expressed as [3]:

$$EE(\frac{MJ}{MJ}) = \frac{\text{product energy content } (\frac{MJ}{ha.yıl})(\text{output})}{\text{enegy used for production } (\frac{MJ}{ha.yıl})(\text{input})} \quad (1)$$

where EE is energy efficiency.

The energy efficiency calculation includes the energy content of the product and the comparison of the energy consumed. The main limits in the calculation of the energy efficiency method include economy-related inputs such as fossil fuels and fertilizers/manures, and labor-based energy inputs.

2.3.1 Energy input calculations

Energy in agricultural systems is generally examined under two main categories: direct and indirect energy use. Direct energy includes the use of electricity, fuel, oil, coal, petroleum products, natural gas, biomass, etc., which are related to the fuel use. Indirect energy, on the other hand, is the energy required for human and animal labor, agricultural implements, fertilizers/manures, pesticides, irrigation, and seed production [20]. Table 1 shows the direct and indirect energy sources included in this study.

Table 1 The Direct and Indirect Energy Sources and Related References Included in This Study

Direct Energy Sources	Indirect Energy Sources
Fuel use for the tractor [3]	Fertilizer and manure production [3]
Fuel use for chainsaw [3]	Tractor production, maintenance, and repair [3]
	Human labor [20]
	Animal labor [20]

The direct energy sources were limited to the use of fuel for the tractor and chainsaw as shown in Table 2. The engine power of agricultural implements (tractor and chainsaw), given in horsepower (HP), were converted to MJ and an additional 23% value was added for the extraction, processing, transportation and refining of final products and crude oil [3]. Indirect energy sources were listed as fertilizer/manure production, tractor production, maintenance and repair, animal, and human labor (Table 2).

The energy content of sheep and goat manure was calculated as 15.4 kcal/kg and the energy content of chicken manure was as 1.033MJ/kg with the renewable energy (grass for sheep and goats) found in the feed used by animals being included [3, 21]. The energy retained in chemical fertilizers were 47.1 MJ/kg chemical-N, 15.8 MJ/kg P2O5 and 9.3 MJ/kg K2O [3].

While calculating the amount of energy arising from the production, maintenance and repair of the tractor, the power of the tractor is converted into the mass of the tractor and the energy amount corresponding to the mass of the tractors is taken as 144 MJ/kg. When calculating the amount of machinery needed for a particular operation (kg/ha/year), the mass amount corresponding to the tractor's power (kg) is multiplied by the tractor's operation time (h/ha/year) and divided by the life of the machine (h) [3].

Table 2 shows the amount of mass corresponding to the power of the tractor and the lifetimes of the machines to calculate the amount of machine needed for a particular operation.

Table 2 The Power, Working Capacity, Weight, and Life of Tractors [22]

Tractors	Weight (kg)	Life (year)	Working time	Usage (hour/year)	Life (hour)
Tractor 0-29kW (0-40 hp)	1900	12	Hour	500	6000
Tractor 30-64kW (41-87 hp)	3300	12	Hour	600	7200
Tractor 65-94kW (88-128 hp)	5300	12	Hour	600	7200
Tractor 95-128kW (129-163 hp)	6450	12	Hour	600	7200

The energy input originating from the human labor used in the production process is expressed as follows [20]:

$$\mathbf{IE} = \frac{(\mathbf{0,268\ x\ Lf\ x\ WDlf\ x\ WHlf}) + (\mathbf{0,268\ x\ Lh\ x\ WDlh\ x\ WHlh})}{\mathbf{IA}} \quad (\mathbf{2})$$

where IE is labor energy (MJ/ha/year); Lf, Lh, family labor and hired labor (person); number of days worked (days/year) for WDlf, WDlh, family workforce and hired workforce; daily working time (hr./day) for WHlf, WHlh, family workforce and hired workforce; IA is the area worked (ha)

To calculate animal labor, following coefficients were used for the fieldwork; for horse use power was 0.50 kW and time utilization coefficient was 71% while for ox use the power was 0.40 kW and time utilization coefficient was 70% [20]. In our study area main animal labor was carried through horses.

2.3.2 Energy output calculations

Energy output was calculated by multiplying the yield (kg/ha/year) with the energy content of the olive (MJ/kg) where the energy content of 1 kg of olives was taken as 7.1 MJ [3].

3. RESULTS

3.1 The Major Differences Between Organic and Conventional Olive Production

The production method of conventional and organic olive groves had many similarities as well as differences. Within the scope of the study, one-on-one interviews were conducted with 37 conventional producers and 27 organic producers in 2015, and 32 conventional producers and 24 organic producers in 2016. Table 3 summarizes the major steps of olive production. Organic farmers mostly used manure or certified organic fertilizers whereas conventional farmers applied 15-15-15 NPK or 20-20-0 NP fertilizers intensively. In addition, conventional producers also applied ammonium sulfate fertilizer, 20-20-20 NPK fertilizer, manure, smart manure, organic manure, triple super phosphate, or potassium sulfate fertilizers. For disease control, both conventional and organic farmers used bordeaux mixture, whereas conventional farmers also used fly traps with pesticides in addition to leaf fertilizer, pesticides for olive moth and/or black scale. Regardless of organic or conventional, none of the farmers irrigated their olive groves.

Table 3 Comparison of Organic vs. Conventional Olive Production Steps in 2015 and 2016.

Year	2015				2016			
Application	Organic		Conventional		Organic		Conventional	
Fertilizer Application	Yes	No	Yes	No	Yes	No	Yes	No
	9	18	11	13	31	1	36	1
Only Manure	9		3		11		3	
Only Synthetic Fertilizer	0		31		0		25	
Both Manure and Synthetic Fertilizer	0		2		0		3	
Pest / Disease Control	Yes	No	Yes	No	Yes	No	Yes	No
	7	20	6	18	8	24	9	28
Use of Bordeaux Mixture and/or Certified Organic Pesticides	7		6		6		2	
Pesticide Use	0		1		0		1	
Bordeaux Mixture and Pesticide Use	0		2		0		5	
Weed Control	Yes	No	Yes	No	Yes	No	Yes	No
	21	6	9	15	24	8	37	0
Only Plowing	13		8		4		4	
Only Mowing	5		16		3		7	
Both Plowing and Mowing	3		3		2		3	
Herbicide Application	0		7		0		10	
Mowing and Herbicide Application	0		3		0		0	
Plowing Process	Yes	No	Yes	No	Yes	No	Yes	No
	16	11	14	10	16	16	11	26
with Tractor	7		3		8		10	
with Horse	5		3		3		3	
with both Horse and Tractor	4		5		3		3	
Pruning	Yes	No	Yes	No	Yes	No	Yes	No
	24	3	15	9	27	5	37	0

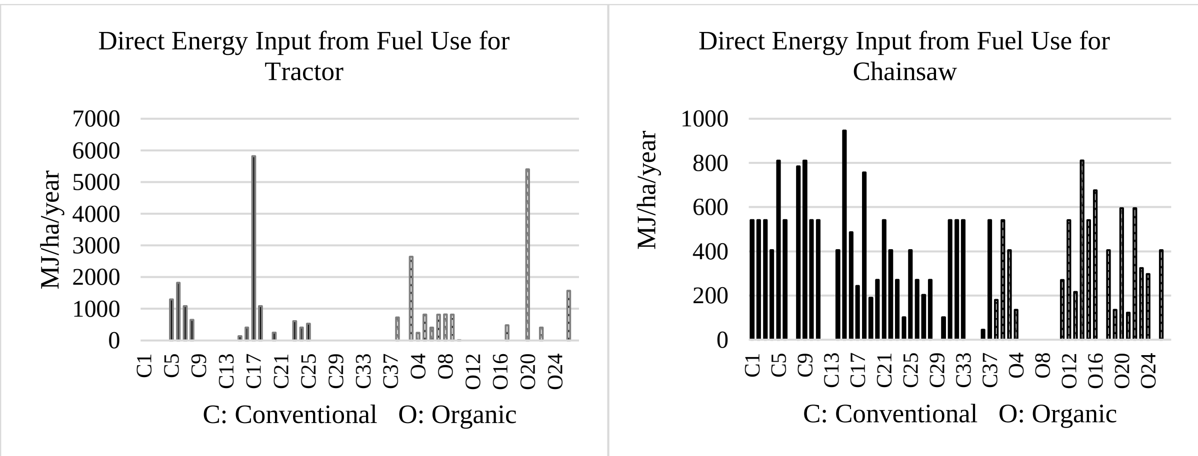
3.2 Comparing the Energy Efficiency of Organic vs. Conventional Production

We compared the conventional and organic farming practices, direct energy use (direct energy input from fuel use for tractors and chainsaws) and indirect energy use (from fertilizer/manure production, tractor production, maintenance and repair, human labor, and animal labor) for the years 2015 and 2016. (Table 4). Also, the energy efficiency of organic and conventional farming practices was compared (Table 5). Mann-Whitney U Test, a non-parametric test used for non-normal distributions was applied using the software SPSS. In both years, there was a significant difference between organic and conventional farming in terms of energy use ($p < 0.0001$) (Table 4). Organic farming needed less energy input due to using manure, a by-product of local animal husbandry, whereas conventional farming used synthetic and industrial fertilizer which required more energy input due to the production prosess (Table 4). Fig. 3 and 4 shows individual farmers' energy input where difference between fertilizer input can clearly be seen. There was no significant difference between the direct energy inputs due to the use of fuel for tractors, chainsaws; indirect energy inputs from tractor production; maintenance and repair; human labor indirect energy inputs; and indirect energy inputs arising from animal labor with 95% confidence ($p > 0.05$) (Table 4).

Total energy use in 2015 and 2016 was significantly different between the two groups (Table 4). The total energy use of conventional agricultural practices was higher due to the high indirect energy input from the production of synthetic chemical fertilizers.

Table 4 Comparison of Energy Use Between Organic vs. Conventional Tests (** indicates statistical significance according to Mann-Whitney non-parametric U Test)

		Mean Energy (MJ/ha/yr)			Mean Energy (MJ/ha/yr)		
		Year 2015			Year 2016		
		Conv.	Org.	p-value	Conv.	Org.	p-value
		N = 37	N = 27		N = 32	N = 24	
Direct Energy	Fuel Use (Tractor)	380.38	561.55	0.231	446.56	764.16	0.914
	Fuel Use (Chainsaw)	381.84	266.44	0.086	381.47	337.28	0.578
	Total Direct Energy Use	762.22	828.00	0.940	828.03	1101.44	0.491
Indirect Energy	**Fertilizer/ Manure Production****	3164.41	367.19	< **0.0001**	4047.5	2499.32	< **0.0001**
	Tractor Production, Maintenance, Repair	134.41	200.92	0.219	125	269.12	0.957
	Human Labor	183.78	215.92	0.145	125.19	130.16	0.803
	Animal Labor	8.68	16.95	0.262	21.6	26.09	0.585
	Total Indirect Energy Use**	3491.28	800.99	< **0.0001**	4319.29	2924.69	< **0.0001**
Total Energy	**Total Energy Use****	4253.49	1628.99	< **0.0001**	5147.32	4026.13	< **0.0001**



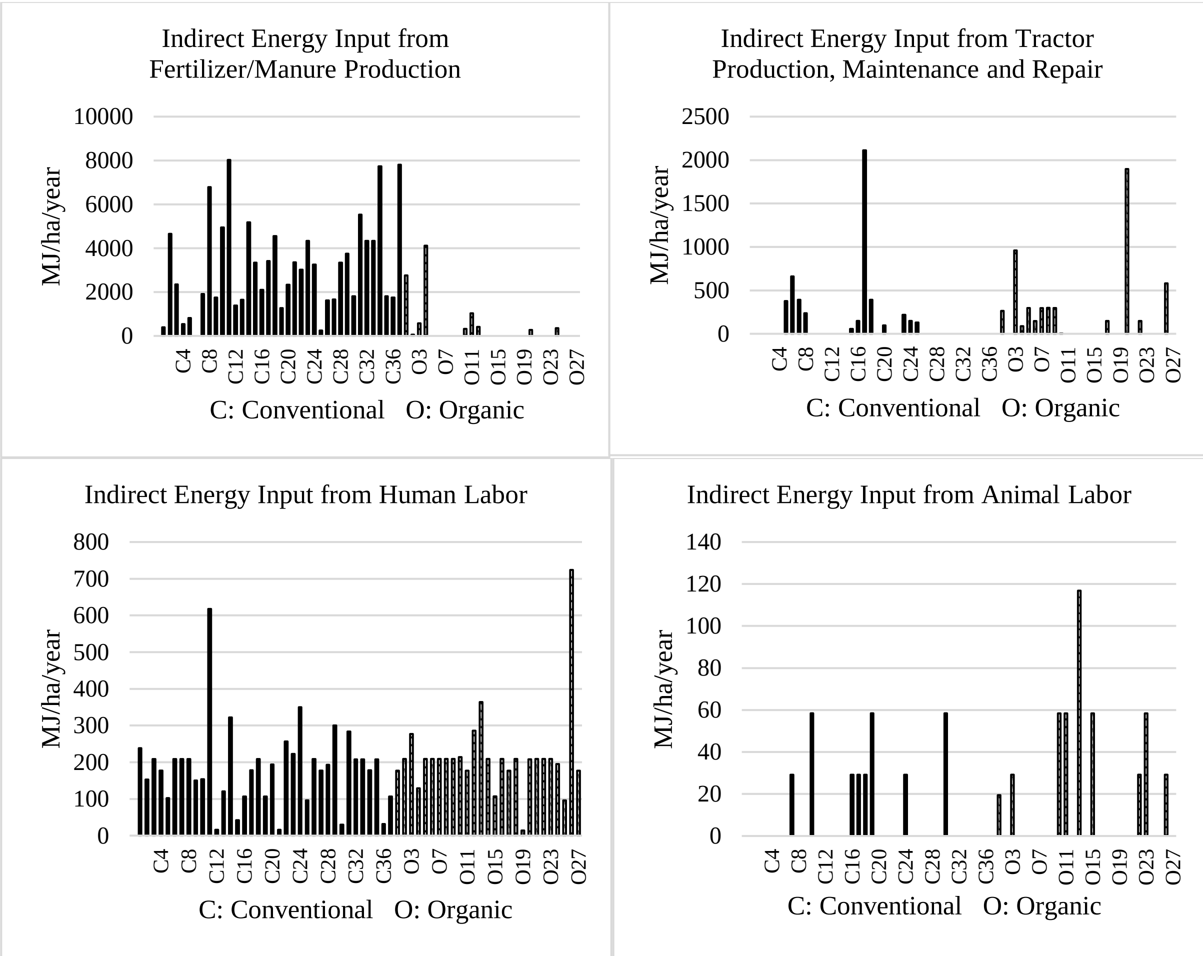
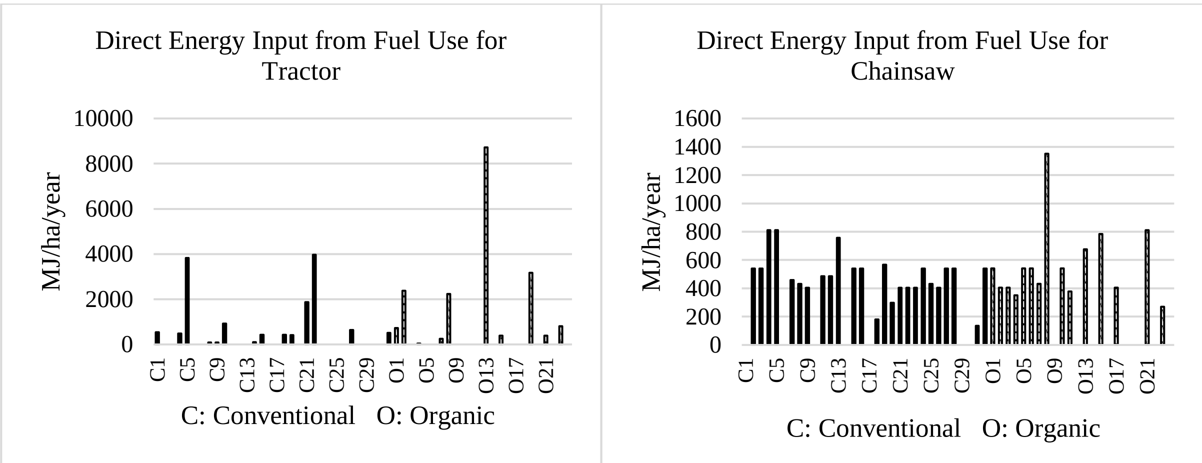


Fig. 1. Energy usage of producers in 2015



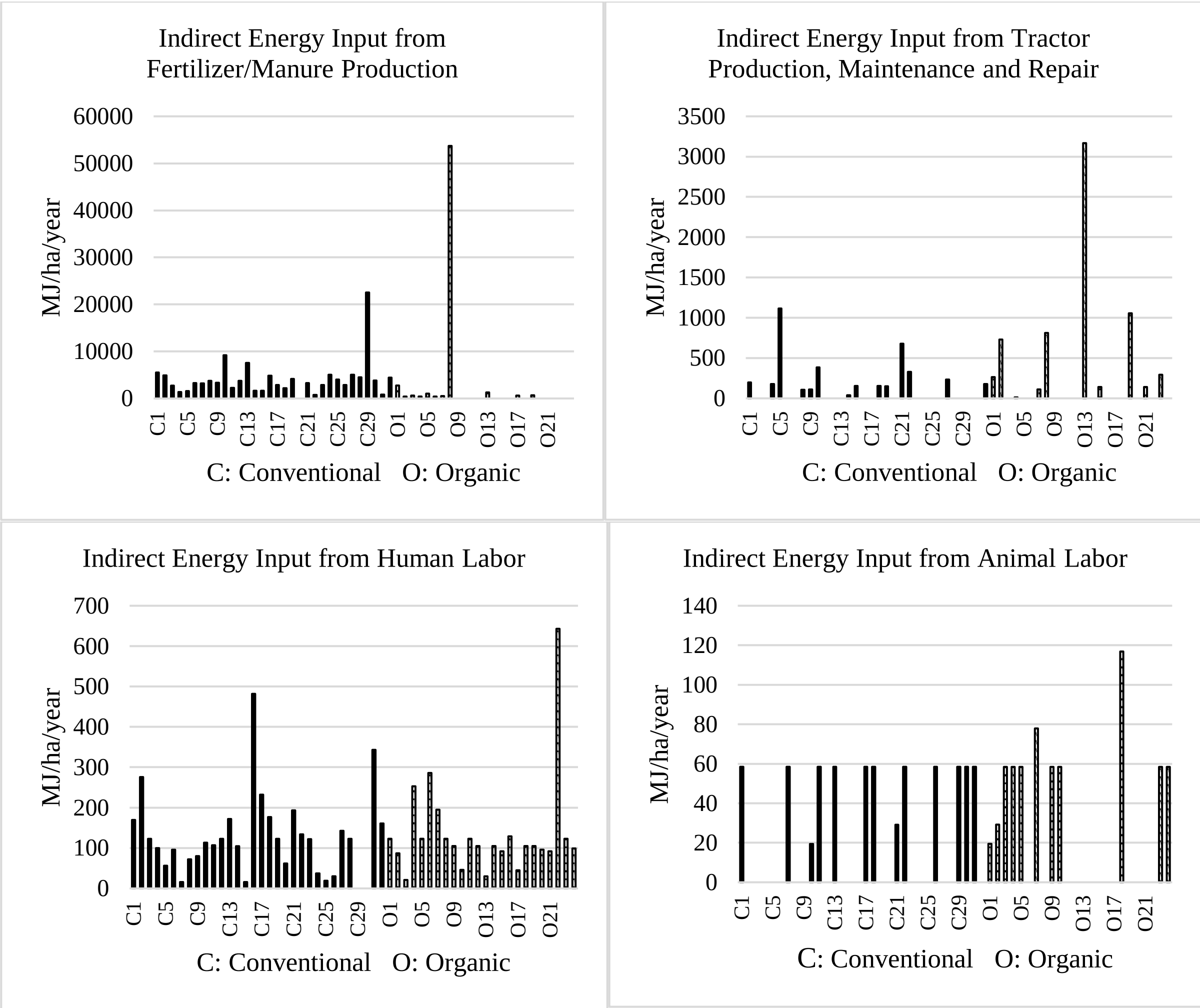


Fig. 2. Energy Use of Producers in 2016

3.2.1 Comparison of Energy Efficiency

To compare energy efficiency of organic and conventional farming Mann-Whitney U Test, a non-parametric test used for non-normal distributions was applied using the software SPSS. There was statistically significant difference between the energy efficiency of conventional and organic farming practices ($p < 0.0001$) (Table 5). Organic farming practices were more energy efficient than conventional farming practices (Fig. 5 and Fig. 6). The reason is the high indirect energy input from chemical fertilizer production in conventional agricultural practices.

Table 5 Energy Efficiency Analysis Results for 2015 and 2016 (** indicates statistical significance)

	Conventional	Organic	p-value
Mean Energy Efficiency 2015**	25.76	180.23	< **0.0001**
Mean Energy Efficiency 2016 **	24.56	220.63	< **0.0001**

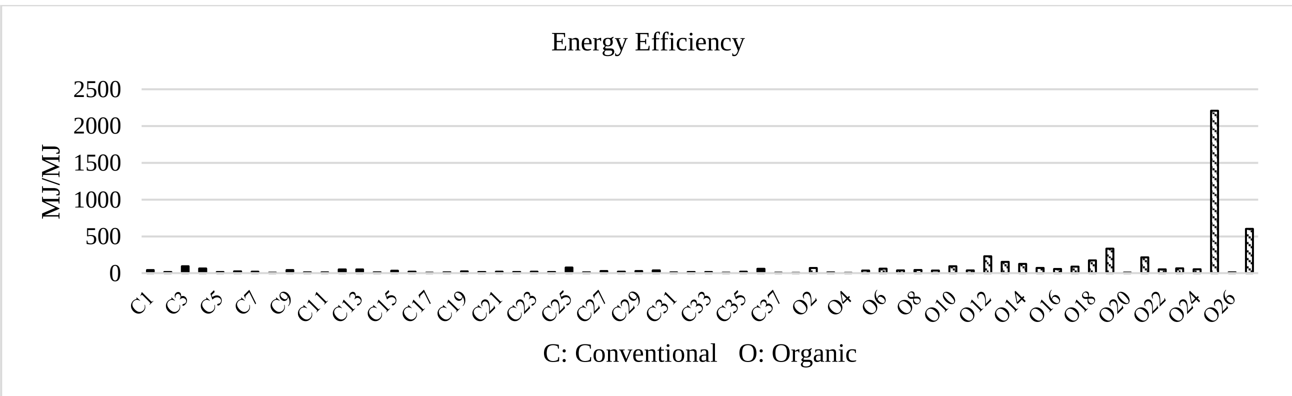


Fig. 5. Energy Efficiency of Producers in 2015

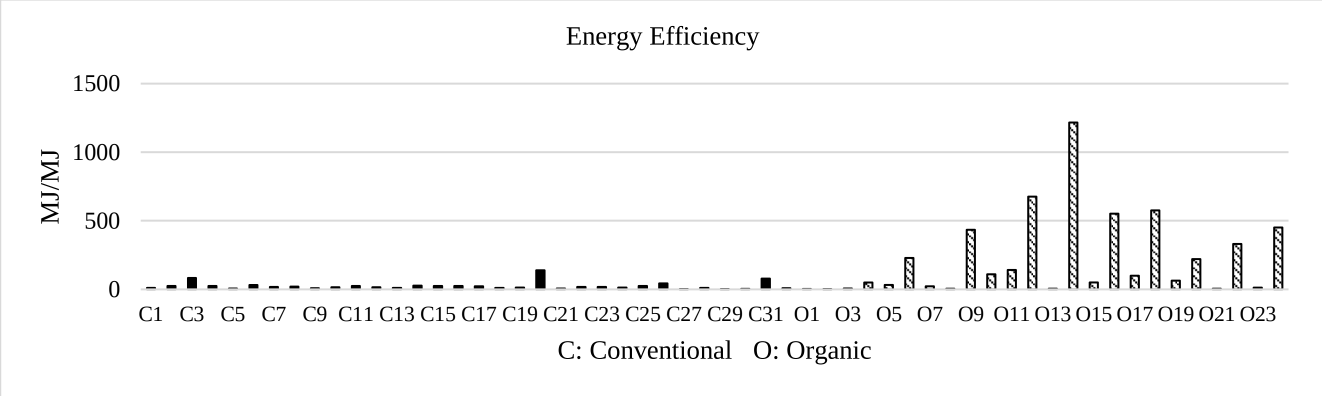


Fig. 6. Energy Efficiency of Producers in 2016

3.3 Comparison of Yield Between Conventional and Organic Olive Production

Biennial bearing is observed in olive trees of Çanakale region, which means trees have full production in one year, and only a few olives in the next year. Therefore comparing yield requires collecting data for two subsequent years. For this part of the study only farmers providing data for both of the years included. 36 producers in conventional and 13 in organic producers provided information for both years, and their data were used to compare olive yield (Fig. 7). Data did not follow a normal distribution therefore a non-parametric Mann-Whitney U Test were carried out using SPSS. The results indicate that the amount of yield changed from farmer to farmer yet there was no statistically significant difference between two farming methods (Mann-Whitney U Test, $p > 0.05$, NConventional = 36, NOrganic = 13) (Fig. 7, Table 6). This result shows that yield does not differ between the farming type.

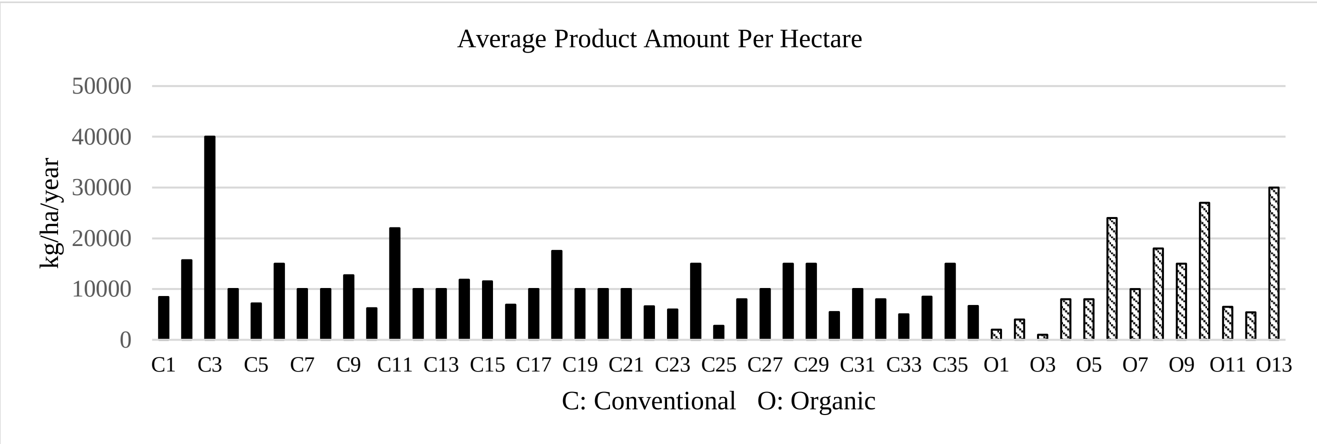


Fig. 7. Average of Production Amounts of Producers in 2015 and 2016

Table 6 Comparison of the Yield Between Conventional and Organic Farming (average yield of two subsequent years)

2015-2016					
	Application Type	Sample Size	Average (kg/ha/year)	Applied Test	Significance Value (p)
Average product quantities	Conventional	36	11,171.46	Mann-Whitney U Test (non-parametric test)	0.673
	Organic	13	13,455.38		

3.4 The Relationship Between the Yield and Energy Input

A multiple regression analysis was performed to determine if there were a relationship between the yield, the amount of fertilizer, total energy use and presence of plowing. Amount of fertilizer or total energy use did not affect the crop amount ($p > 0.05$) (Table 7). There was no significant relationship between the increase in energy use and the amount of fertilizer and the yield. On the contrary, as the amount of fertilizer, and/or the number of processes increased energy efficiency decreased yet yield did not change. For instance, farmers who do tillage using tractors had lower energy efficiency both because of direct fuel consumption and because of indirect effects such as tractor producer, maintenance, and repair, whereas farmers managed weeds by mowing had lower energy use and very similar yield.

Table 7 The Relationship Between Crop Amounts and Fertilizer Amount, Total Energy Use and Tillage

	Number of Samples	Adjusted R^2	Significance value (ANOVA test) (p)	Significance Value (p)
Yield				
Fertilizer/manure Amount	49	0,038	0,196	0,436
Total energy input				0,633
Presence of Plowing				0,095

No significant relationship was found between energy use and yield, and it was concluded that it would be possible to produce similar yield with less energy input. If energy efficiency is improved, the technical performance of agricultural systems can be increased and negative impacts on the environment can be reduced.

4. DISCUSSION AND RECOMMENDATIONS

This study compared two types of olive groves in terms of energy efficiency, and yield. The yield did not differ between two farming types, however conventional olive farms proved to be less energy efficient. The reason was mainly due to the use of synthetic fertilizers. In the study area, organic farmers preferred to use local products (i.e., locally produced manure, a by-product of local animal husbandry), as a result the energy need for growing olives were lower, while producing similar yield. Many studies find similar results to ours, for example in a study conducted by Dessane (2003) in Greece, organic olive groves were twice as energy efficient as conventional olive groves [3]. Guzman and Alonso's (2008) study in Spain revealed that organic olive cultivation has higher non-renewable energy efficiency compared to conventional olive cultivation [11]. Kavargiris et al. (2009) in their study in Greece determined that organic agriculture had a lower energy input and was more energy efficient than conventional agriculture, and therefore it was more economical [8].

This study proved that the most energy input was due to the fertilizer production and fuel use for the tractor. The energy input can considerably be reduced by decreasing the use of synthetic fertilizers. Also decreasing the use of tractor by mowing instead of plowing and increasing the use of animal labor can be given as recommendations to decrease energy input. Also, the use of renewable energy sources instead of non-renewable energy sources may be the most appropriate management method for increasing energy efficiency. One recommendation can be solarization [23], which not only decreases weed biomass but also helps increasing soluble nutrients in soil, which in turn decreases the need for fertilization [24]. However, this method can only be applied in hot regions, and it might have additional environmental effects due to the use and production of plastic, a non-renewable source. By adding a certain amount of bioethanol to the fuel, the consumption of petroleum products and air pollution can also be reduced. But there are legal issues and problems with biomaterial production. Biodiesel, which is obtained by adding methyl alcohol to oils, is a more environmentally friendly and more advantageous energy source than diesel and gasoline. Biogas is a more environmentally friendly energy source than gasoline and diesel, which is formed because of anaerobic fermentation of organic wastes. In addition, the wastes released because of anaerobic fermentation can be used as fertilizer since they have nutritive properties [23].

This study shows that by making small adjustments in farming, such as using manure instead of syntetic fertilizers, or decreasing the use of tractor and plowing it is possible to have significant impacts on energy efficiency while obtaining same amont of yield. By improving energy efficiency, the technical performance of agricultural systems can be increased and their negative impact on the environment can be reduced.

Acknowledgments
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