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Evaluation of Energy Efficiency, Emission of Greenhouse Gases and Production Function in Olive (*Olea europaea*) Production in Ilam Province, Iran

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Abstract

Sustainable crop production in any region is subject to the production energy flow. Paying attention to the inputs and outputs in the production system regarding environmental management is important. In this study, energy consumption in olive production as well as the greenhouse gas emissions in Ilam province, were investigated in 2019. The survey was conducted on a population of 195 olive farmers. The information was collected using a face-to-face interview utilizing a questionnaire. Results have shown that the total input energy for olive production was 15107.17 $MJ.ha^{-1}$, while the total output was 34389.7 $MJ.ha^{-1}$, making the energy efficiency and energy productivity 2.28 and 0.19 kg MJ^{-1} respectively. Electricity (37.04%) and nitrogen fertilizer (27.74%) are the highest sources of energy intended for olive production in Ilam. The result from the Cobb-Douglas function has revealed that olive production in Ilam province is significantly affected by electricity, irrigation and workforce with 0.45, 0.27 and 0.13 regression coefficients respectively. The total emissions of greenhouse gases were equivalent to 1 kg of carbon dioxide per hectare. Electricity was found the most greenhouse-gas emitting agent (80.1%). Non-renewable energy was applied more than renewable energy. In Ilam province, the reduction of non-renewable energy allows for increase of energy efficiency; however, this requires appropriate mechanization methods to produce olives.

Keywords: Energy efficiency, Energy productivity, Greenhouse gases, Olives.

INTRODUCTION

Olive (*Olea europaea* L.) is a member of Oleacea family, Olea cultivar and its homeland is Upper Mesopotamia, covering South-eastern Anatolian Region and South AsiaMinor. Olive can be consumed directly, or it can be used to produce oil. Olive oil is natural fruit oil produced through physical methods only and contains unique antioxidant matter (phenolic compounds, tocopherol, and other aromatic matters) (Gökdoğan and Erdogan, 2021). Olives originated from the Mediterranean region. In recent years, their cultivation has expanded worldwide, especially in Iran, due to the high nutritional value of fruits and oils (Abbasi *et al*., 2012). Olive oil production is one of the most essential food industries in the Mediterranean basin (Romaniello *et al*., 2019). The area under olive cultivation in Iran is estimated to be 78000 hectares, of which 600 hectares are situated in Ilam province. Sustainable production of agricultural products, such as olives requires attention to the trend and flow of energy consumed during the production process. Iran is one of the largest producers of energy from non-renewable sources. About 99% of energy in Iran comes from non-renewable sources such as natural gases and petroleum derivates (Bakhoda *et al.*, 2012).

The world's population is growing: from about 7.8 billion people in 2020, it is predicted that this figure could increase to 8.5 people in 2030, 9.7 people in 2050 and 10.9 people in 2010 (Heydar *et al*., 2022). The global trend towards more population will increase the attention to global consumption of food. Currently, living standards are expected to improve, requiring more per capita consumption of animal, vegetable oils and processed foods. The combination of increasing world population with improving living standards will drastically affect energy consumption. According to the report of the Food and Agriculture Organization of the United Nations (Wei *et al*., 2022), the agricultural food sector currently accounts for about 30% of the world's total final energy consumption (Gong *et al*., 2021).

Agriculture is both a consumer and a producer of energy. In agricultural processes, solar radiation, and energy from fossil fuels, electricity and workforce are converted into food and other products humans need (Gökdoğan and Erdogan, 2021; Karaağaç *et al*., 2019; Heydari and Maleki, 2014; Heydari *et al*., 2011). In the past, agricultural activities relied mainly on workforce and livestock. In contrast, today agricultural production relies on the consumption of non-renewable fossil fuels due to all the machinery in use. Excessive consumption of fossil fuels has harmful environmental consequences due to increased carbon dioxide and other greenhouse gas emissions into the atmosphere (Emami *et al*., 2019; Shamsibeiranvand *et al*., 2017; Karaağaç *et al*., 2019; Mirzaei-Heydari, 2013).

The advent of machinery, fossil fuels and electricity, which coincided with advances in science and technology, has revolutionized food production worldwide. Energy consumption in agriculture has increased in response to population growth, a limited supply of arable land, and a tendency to raise living standards (Kafkaletou *et al*., 2021; Ganjineh *et al*., 2019; Maleki *et al*., 2014; Bahamin *et al*., 2019; Eren *et al*., 2019; Aydın and Aktürk, 2018). The world's agricultural production system has changed due to mechanization, fertilizers and chemical pesticides, and suitable seeds. This change in the energy consumption pattern has created problems such as environmental warming caused by greenhouse gas emissions, and water and soil pollution (Tamborrino *et al.,* 2020). When producing agricultural products there is direct and indirect energy consumption. Energy is used directly by tractors, motor pumps, dryers and other machinery including the electrical energy used by electrical motors. Energy is consumed indirectly to manufacture farm equipment, fertilizers, pesticides, as well as for food processing and transportation (Gökdoğan and Erdogan, 2018; Fathi and Bahamin, 2018; Foladvand *et al*., 2017; Tamborrino *et al*., 2021).

In recent years at the global level, there is an increase in attention to the paradigm of sustainability and sustainable use of resources. In the agriculture and food sector, the initial efforts in producing agricultural products have included both the optimization of the use of resources and the use of renewable energies (Perone *et al*., 2022; Servili *et al*., 2019). Significant contributions will also be made from the move towards more sustainable activities in the food sector, mainly through increased investment in renewable energies and improvements in energy efficiency (Tamborrino *et al*., 2021). The goal is to produce more with less energy consumption. In this regard, one of the main principles of sustainable production is the improvement between energy inputs and desired outputs of a process, i.e. improving energy efficiency (Rapa and Ciano, 2022).

In the agricultural industry, energy consumption has increased. Hence, increasing productivity in this field. However, energy efficiency has decreased due to the scarcity of natural sources and the effect on human health and the environment. The need to study energy consumption patterns in the agricultural process has become vital (Tamborrino *et al*., 2021; Kardoni *et al*., 2019; Khoshnevisan *et al.*, 2013). The relationship between input energy and performance was estimated using the Cobb-Douglas function it showed that seed and water energy with coefficients of 2.57 and 1.51 respectively had the most positive effect on soybean yield (Asgharipour *et al.*, 2020).

Due to an increase in the area under olive cultivation in Ilam province in recent years and the lack of study in the field of energy consumption in the production of this product, it is necessary to study this field. This study was evaluated to investigate the course of energy and the role of energy inputs on olive yield in Ilam province.

MATERIALS AND METHODS

Study area and sampling method

Ilam Province is located between 33 degrees 21 minutes and 33 degrees 51 minutes north, and 45 degrees 41 minutes and 46 degrees 51 minutes east. The statistical population was all olive growers in Ilam province. A simple random sampling method and Cochran's formula (I) were used to estimate the sample determination volume (Singh *et al*., 2002).

$$n = \frac{Nt^2 S^2}{Nt^2 + t^2 S^2} \quad (I)$$

Where N is equivalent to the size of the statistical population or olive growers, t is an acceptable reliability coefficient assuming that the distribution of the desired trait is expected from the t-table, S^2 is the estimated variance of energy proportion in the statistical population of the experimental area, and n is the sample size. In random sampling, each member of the defined community has an equal and independent chance of being included in the sample.

Independence means that the choice of a member dose not affect the choice of other members of society. Finally, according to the statistical population of 310 people in the present study, a statistical sample of 177 people was taken.

Energy consumption analysis

The energy equivalents of input and output used in olive production in Ilam province are presented in Table 1.

Labor energy (Ela)

The use of labor power and energy for agricultural operations is widespread in different regions of Iran. The measurement of labor and energy expenditure by workers in various agricultural operations due to the complexity of the body and worker structure and the combination of movements and tasks, is very complex (Kazemi *et al.*, 2015). In this study, to calculate total labour energy, relationship (II) was used.

$$\text{Soil preparation} + \text{irrigation} + \text{fertilization or fertilizer} + \text{pruning} + \text{harvesting} + \text{transfer of the crop to the machine} = \text{labor energy} \quad \text{(II)}$$

Energy

Irrigation water energy was determined by multiplying the amount of water consumption in the period (crop year) by m^3 by the amount of its equivalent.

Fuel energy and irrigation water

To calculate the energy consumption of fuel in different operations (fuel consumption for operation, harvesting and crop transferring) relationship (III) was used (Mohammadi *et al.*, 2008):

$Efp = Qi \times Efp$ (III), where Efp represents the fuel energy (MJ ha^{-1}), Qi is the amount of fuel consumed (liters per hectare), and Efi is the energy equivalent to each unit of fuel (MJ $Liter^{-1}$).

Electricity

The electrical energy for water supply from irrigation wells in this study was calculated from equation (IV) (Mohammadi and Omid, 2010):

$$DE = \frac{ygHQ}{Sp}$$

(IV), where, DE is the electricity energy (giga-watt/hectare), y is the water density (its amount is 1000 kg/m3), g is the gravitational force (9.8 m/second square), H is the average water pumping depth, Q is the special water requirement of the plant (cubic meters/hectare), and Sp the total efficiency of irrigation energy conversion (its value was considered to be 0.18 to 0.2 for electric wells).

The energy of machines

In the studied areas, olive cultivation used step-by-step machinery for spraying and plowing between trees. The tractor was an ITM 285 model. The energy of machinery was obtained using the following equation (V) (Kazemi *et al.*, 2015):

$$ME = E\frac{G}{T}Qh$$

(V), In this equation, ME is the energy of machines in terms of mega-joules per hectare (Mj ha-1), E is the energy of machine production, G is the weight of the machine in kilograms (kg), T is the useful life of the machine in hours (h), and Qh is the total amount of machine hours per hectare (h ha^{-1}).

The energy of fertilizers and chemical pesticides

In this study, two types of phosphorus and nitrogen fertilizers were used, they are common in the region, but potash fertilizers were not used. The energy required for chemical fertilizers was calculated using equation (VI) (Ozkan *et al.*, 2004):

$$Efp = Qi \times Efi$$

(VI). In this regard, Efp was the energy of fertilizer (Mj ha^{-1}), Qi was the amount of fertilizer or poison used (kg ha-1), and Efi was the energy equivalent of each unit of fertilizer (MJ kg^{-1}). Organic fertilizers are part of biological crop energies and renewable resources and can be an excellent alternative to chemical fertilizers in the country's farms (Ozkan *et al.*, 2004; Royan *et al.*, 2012).

Calculation of energy indices

After determining the input and output energies of olive production in Ilam province, energy indicators were calculated (Tipi *et al.*, 2009; Mobtaker *et al.*, 2010). Energy efficiency represents the amount of energy consumed per hectare in olive production. The energy used as the harvest are calculated in equation (VII).

$$\text{Specific energy} = \frac{\text{energy input (MJ ha} - 1)}{\text{olive oil output (kg ha} - 1)}$$

(VII)., Energy efficiency indicates that for each megawatt of energy consumed per hectare, a few kilograms of crop are obtained. The value was calculated using equation (VIII).

Pure energy based on relationship (IX) indicates the energy output from the farm. Negative numbers indicate that energy has not been released as much as energy has entered the farm, resulting in inefficient energy consumption.

$$\text{Net energy} = \text{energy output (MJ ha} - 1) - \text{energy input (MJ ha} - 1) \quad \text{(IX)}$$

Equation (X) was used to estimate the energy consumption to produce a unit of the product, thus, calculate the energy necessary to produce a kilogram of olives.

$$\text{Energy ratio} = \frac{\text{energy output (MJ ha} - 1)}{\text{energy input (MJ ha} - 1)}$$

(X).In this study, the share of direct energy forms (electricity, irrigation water, labor and fuel), indirect forms (chemical fertilizers, animal manure, chemical pesticides and machines), and renewable energy (irrigation water, labour force and animal manure) and non-renewable energy (electricity, fuel, chemical fertilizers, chemical pesticides and machines) in olive production were studied in Ilam province.

Table 1. Energy equivalents of input and output in olive production systems.

	Items	Unit	Energy equivalents	Reference
Inputs	Human labour	H	1.96	Rajaeifar *et al.* (2014)
	Machinery	H	62.7	Ghorbani *et al.* (2011)
	Diesel fuel	L	47.8	Erdal *et al.* (2007)
	Gasoline fuel	L	46.3	Mobtaker *et al* (2010)
	Chemical fertilizer	kg		
	(a) Nitrogen		78.1	Mohammadshirazi *et al.* (2012)
	(b) Phosphate		12.44	Mohammadshirazi *et al.* (2012)
	(c) Farmyard manure		0.3	Rajaeifar *et al.* (2014)
	Chemicals	kg	120	(Mohammadi *et al.*, 2010)
	Electricity	kwh	3.6	Rajaeifar *et al.* (2014)
	Water for irrigation	m^3	0.63	Rajaeifar *et al.* (2014)
	Seed	kg	14.7	Rajaeifar *et al.* (2014)
Output	Olive	kg	37.6	Rajaeifar *et al.* (2014)

In this study, to estimate the relationship between the input energies of workforce, machinery, diesel, gasoline, nitrogen, phosphorus, animal manure, chemicals, electricity and irrigation water for olive production, the Cobb-Douglas function was used. The latter has been credited by many researchers in the study of the energy consumption of agricultural products (Rajaeifar *et al.*, 2014; Nikkhah *et al.*, 2014; Wolf *et al.*, 2010). The Cobb-Douglass production function can be expressed in equation (XI).

$$Y = f(x)\ exp\ (u)$$

(XI),Equation (XI) can be expressed in the form of a linear equation as follows:

Model A: $\ln Yi = \alpha 0 + \sum_{j=1}^{n} \alpha j \ln(Xij) + ei\ ;\ \ i = 1,2,\ldots,195$ (XII)(Asgharipour *et al.*, 2020), where Yi is the yield of olive oil from the i[th] farmer; Xij is the vector of inputs used in the production process, α_0 is the constant term, αj represents coefficients of inputs which are estimated from the model, and that is the error term (Singh *et al.*, 2002; Tabar *et al.*, 2010).There is a general assumption that if there is no input energy, the crop production is considered zero (Rajaeifar *et al.*, 2014; Pishgar-Komleh *et al.*, 2013; Hemmati *et al.*, 2013) and the constant term α_0 can be excluded from equation (XII) to reduce it (XIII):

$$\ln Yi = \sum_{j=1}^{n} \alpha j \ln(Xij) + ei \;\; ; \; i = 1,2, \ldots ,195$$

(XIII), where E_{hl} is human labour energy, E_f is fuels energy (includes gasoline, diesel and natural gas), E_{cb} is chemical biocides energy, E_{cf} is chemical fertilizers energy, E_{fym} is farm yard manure energy, E_{el} is electrical energy and Ewi is water for irrigation energy (due to low share of machinery energy input from total energy, machinery inputs were omitted from the model). The effects of direct energy (E_d), indirect energy (E_{id}), renewable energy (E_r) and non-renewable energy (E_{nr}) on output (olive oil as the final product) were determined by developing the model B and C as follows (Asgharipour *et al.*, 2020):

Model B: $\ln Yi = \beta 1 \ln Ed + \beta 2 \ln Eid + ei$ (XIV)

Model C: $\ln Yi = \beta 1 \ln Er + \beta 2 \ln Enr + ei$ (XV)

Where β_1, β_2, Υ_1 and Υ_2 are coefficients of the variables mentioned.

Greenhouse gas emissions

In this study, the CO_2 emission coefficient was used to assess the amount of greenhouse gases in olive production systems per hectare. Table 2 shows the equivalent of the standard coefficients of greenhouse-gas emissions.

Table 2. Equivalent to the standard coefficients of greenhouse gas emissions

Inputs	Unit	Gas coefficient ($Kg\ CO_{2\ eqa\ Unit}^{-1}$)	Reference
Human labour	h	0.001	Liu *et al.* (2010)
Machinery	Mj	0.071	Liu *et al.* (2010)
Diesel fuel	L	2.76	(Nikkhah *et al.*, 2014)
Farmyard manure	Kg	0.126	Pishgar Komele *et al.* (2012)
Nitrogen	kg	1.3	Pishgar Komele *et al.* (2012)
Herbicide	kg	6.3	Pishgar Komele *et al.* (2012)
Gasoline fuel	L	2.3	(Nikkhah *et al.*, 2014)
Electricity	kWh	6.08	(Koshnewisan *et al.*, 2013)

Data analysis

Data analysis was performed using Excel and SPSS software. Descriptive statistics methods (fertilizer consumption, toxin consumption, etc.) and analytical statistics were used.

RESULT AND DISCUSSION

Energy consumption in olive production in Ilam province is described in Table 3 below. In Olive production systems, electricity, nitrogen and irrigation water accounted for the largest share of total input energy. Moreover, manpower, machinery and diesel had an input of 5.02%, 1.13% and 6.09% respectively of the total input energy. In the study area, field irrigation is traditional and farrowed; drip irrigation is less commonly used. Water consumption is high; due to the need for irrigation, the input of electricity and irrigation water is elevated. A study by Rajaeifar *et al.*, 2014 showed that electricity had the largest share of total input energy in pear production in Iran. The total input energy in the olive production system in Ilam province was 15107 megajoules per hectare. The input energy for olive production in Gilan province was estimated at 19070 megajoules per hectare (Pishgar-Komleh *et al.*, 2012; Bayraktar *et al.*, 2020). The output energy from olive yield in Ilam province is shown in Table 3. The average yield of olives and their output energy equivalent were 2914.38 kg ha^{-1} and 34389.7 MJ ha^{-1}, respectively.

Table 3. Energy consumption in olive production in Ilam province

	Unit	Total energy equivalent (MJ ha^{-1})	Percentage (%)[a]
A. Inputs			
Human labour	h	758.10	5.02
Machinery	kg	171.46	1.13
Gasoline fuel	l	920.21	6.09
Petrol	l	388.07	2.57
Chemical fertilizer			
(a) Nitrogen	kg	4191.42	27.74
(b) Phosphate	kg	383.34	2.54
(c) Farmyard manure	Kg	180.56	1.20
Chemicals	Kg	330.46	2.19
Electricity	kW h	5596.06	37.04
Water for irrigation	m^3	2187.51	14.48
Total input energy	MJ ha^{-1}	15107.17	100.00
B. Output			
Total output energy	MJ ha^{-1}	34389.70	

[a] Percentage from total energy input.

Energy efficiency in olive production was 2.28. The energy efficiency of olive production in this study has been lower compared to the energy efficiency in Gilan province (3.02) (Bayraktar et al., 2020; Cavaca et al., 2020). One of the reasons for the decrease in energy efficiency in this study is lower rainfall and local climate in this region, which has increased the use of irrigation water and electricity. The amount of exploitation in olive production was 0.19 Kg MJ^{-1}. The energy efficiency in olive production of Gilan province were 0.88 Kg MJ^{-1}

and in pear production was 0.27 Kg MJ^{-1}. The net energy and special energy in olive production in Ilam province was 1958.532 MJ ha^{-1} and 5.18 MJ kg^{-1}, respectively. Researchers (Rajaeifar *et al.*, 2014) showed that net energy in olive production is 15532 MJ ha^{-1} and special energy is 12.70 MJ kg^{-1}. The share of direct energy in olive production (65.20%) was higher than the total input energy compared to indirect energy (34.80%). Also, the share of non-renewable energy in olive production (80.50%) was higher than renewable energy (19.50%). Table 3 shows input and output energy equivalent in olive production. The highest value for electricity was 5596.06 MJ ha^{-1}. The lowest value was obtained for machinery at 171.46 MJ ha^{-1}.

Table 4. Energy indices in olive production in Ilam province

Items	Amount	Percentage (%) [e]
Energy use efficiency	2.28	
Energy productivity (kg MJ^{-1})	0.19	
Specific energy (MJ ha^{-1})	5.18	
Net energy (MJ ha^{-1})	19282.53	
Direct energy (MJ ha^{-1}) [a]	9849.94	65.20
Indirect energy (MJ ha^{-1}) [b]	5257.23	34.80
Renewable energy (MJ ha^{-1}) [c]	2945.60	19.50
Non-renewable energy (MJ ha^{-1}) [d]	12161.57	80.50

[a] Includes human labour, diesel fuel, water for irrigation, electricity. [b] Includes seeds, chemical fertilizers, farmyard manure, biocides, machinery.[c] Includes human labour, seeds, farmyard manure, water for irrigation. [d] Includes diesel fuel, electricity, biocides, chemical fertilizers, machinery. [e] Figures in parentheses indicate percentage of total energy input.

The effect of all input energy on olive production using Dab Glass function in Ilam province is shown in table 6. Energy inputs, other than chemical pesticides and animal manure, had a positive effect on olive production. However, only the effect of electricity, irrigation water, and manpower was significant on olive yield. The regression coefficients of different major inputs were 0.45, 0.27 and 0.13 for electricity, irrigation water and manpower respectively. According to regression analysis, 10% increase in electricity consumption, irrigation water and manpower will result in 4.5%, 2.7% and 1.3% increase respectively in olive production. However, 10% increase in animal manure and chemical pesticides leads to a decrease of 2.3% and 1.1% of performance respectively. A similar study on the energy production of olives in Gilan province reported the effects of workforce, electricity and animal manure inputs on positive and significant olive production (Debnath, 2018; Tabatabaie *et al.*, 2013).

Table 5. Olive production function in Ilam province under the influence of inputs

Endogenous variable	Olive yield	
Exogenous variables	α_i	t-Ratio
Model A: $\ln Yi = \alpha1\ln(X_1) + \alpha2\ln(X_2) + \alpha3\ln(X_3) + \alpha4\ln(X_4) + \alpha5\ln(X_5) + \alpha6\ln(X_6) + \alpha7\ln(X_7) + \alpha8\ln(X_8) + \alpha9\ln(X_9) + \alpha7\ln(X_7) + ei$		
Human labour	0.13	2.58*
Machinery	0.21	1.20
Diesel fuel	0.35	0.65
Gasoline fuel	0.14	0.98
Nitrogen	0.22	1.035
Phosphate	0.16	1.41
Farmyard manure	-0.11	0.78
Chemicals	-0.23	0.33
Electricity	0.45	3.85**
Water for irrigation	0.27	3.25**
Durbin-Watson	1.98	
R^2	0.91	

** Indicates significance at 1% and * Indicates significance at 5 % probability level.

The regression coefficients of direct and indirect energies as well as renewable and non-renewable energy on olive yield using the Dab Glass function in Ilam province, are shown in Table 6. Indirect energy has a more significant impact on olive yield than direct energy. A 10% increase in direct and indirect energy consumption leads to an increase of 1.9% and 2.3% of olive yield, respectively. Hence, renewable energy had a more significant impact on olive yield than non-renewable energy. However, an increase of 10% in consumption of renewable and non-renewable energy leads to an increase of 4.1% and 3.2% in olive yield, respectively. Researchers (Goenka and Simon, 2021; Mousavi-Avval *et al.*, 2011) showed that the effect of direct, indirect, renewable and non-renewable energies on olive yield was significant, which is consistent with the results of this study.

Researchers (Pishgar-Komleh *et al.*, 2013) studied the emission of greenhouse gases in potato production in Hamadan province and indicated that the highest amount was related to chemical fertilizers. Nevertheless in another study (Ghane Golmohamadi *et al.*, 2019), the greenhouse gas emissions of wheat were estimated at 2711.58 kg of carbon dioxide per hectare, and electricity had the highest value and was consistent with the results of this study.

Table 6. Econometric estimation of direct versus. Indirect energies, and renewable versus. Non-renewable energies for olive

Endogenous variable	Olive yield	
Exogenous variables	Coefficient	t-Ratio
Model B: $\ln Yi = \beta 1\ln(X_d) + \beta 2\ln(X_{id}) + ei$		
Direct energy	0.19	3.85**
Indirect energy	0.23	4.23**
Durbin-Watson	1.92	
R^2	0.86	
Model C: $\ln Yi = \lambda 1\ln(X_r) + \lambda 2\ln(X_{nr}) + ei$		
Renewable energy	0.41	5.61**
Non-renewable energy	0.32	4.52*
Durbin-Watson	2.01	
R^2	0.88	

** Indicates significance at 1% and * at 5 % probability level.

Table 7. Equivalent to the standard coefficients of greenhouse gas emissions

	Unit	Kg Gas equal CO_2 Per ha	%
A. Inputs			
Human labour	H	1.96	0.29
Machinery	MJ	0.252	0.18
Diesel fuel	L	57.3	3.58
Gasoline fuel	L	17.65	1.66
Nitrogen	Kg	73.3	5.99
Farmyard manure	Kg	82.45	6.46
Herbicide	kg	10.15	0.8
Electricity	kwh	953.3	79.3
Water for irrigation	m^3	0.63	(Yousefi *et al.*, 2014 a and b)
Seed	kg	14.7	(Yousefi *et al.*, 2014 a and b)
B. Output			
Olive	kg	37.6	Rajaeifar *et al.* (2014)

The total emission of greenhouse gases in olive cultivation was 1201.1 kg of carbon dioxide per hectare. Electricity emissions accounted for 79.3% of the greenhouse gas emissions, with livestock manure at 6.46% and nitrogen fertilizer at 5.99. The lowest greenhouse-gas emission in olive production was related to machinery with 0.252%.

CONCLUSION

The total incoming energy for olive production in Ilam province was 15,107 MJ ha^{-1}. Due to traditional irrigation in the region, electricity has the largest input, estimated to 37% of the total energy input. The lowest incoming energy was from the animal manure representing only 1.2% of the total energy. To reduce electricity consumption, modern irrigation is advisable in olive production. Energy efficiency and productivity were respectively estimated to be 2.28 kg MJ^{-1} and 0.19 kg MJ^{-1} respectively. Furthermore, net energy was 19282.53 MJ ha^{-1} and special energy was 5.18 MJ kg^{-1}. The results of the economic model have shown that electricity, irrigation and manpower had a significant impact on olive production. The results of this study showed that it is possible to optimise energy consumption.

The difference between the values observed in this study and the ones observed by other researchers in different parts of Iran is a result of climatic conditions, crop operations as well as energy management. However, electricity and chemical fertilizers are the energy-input consumers. In Ilam region, olive production is largely dependent on non-renewable energy. Hence, direct energy accounted for much more than indirect energy. The high consumption of electricity and water in Ilam agriculture is largely due to the low cost of this energy source; water on the other hand is free of charge.

The total emission of greenhouse gases was 1201.1 kg of Carbone dioxide per hectare. Electricity emissions were the most with 79.3% of total emissions. The lowest emissions came from machinery, representing 0.18% of the total emissions. The results obtained in this research in comparison with regional studies showed that due to the conditions of each region, it is possible to reduce or increase and optimize the consumption of inputs. The difference between the values reported in different parts of Iran is due to the difference in management and agricultural operations and weather conditions. But in general, the high energy consumption of inputs such as electricity and chemical fertilizers is quite evident. In this study, a significant increase in the share of non-renewable energy in olive production systems was observed, which indicated the dependence of agriculture in this region on non-renewable energy. The share of direct energies was higher than indirect energies. In the production of olives, electricity accounted for the largest share in input energy consumption. The reason for the high consumption of electricity in the studied area can be considered to be the cheapness of the electricity tariff called the agricultural tariff, which is much cheaper than the normal tariffs. Therefore, solutions should be considered to reduce inputs with high energy consumption. Adopting of suitable mechanisation methods can increase the productivity of renewable energy by reducing the consumption of non-renewable energy.

REFERENCES

Abbasi Y., Bakhshi D., Forghani A., Sabouri A., & Porghauomy M. (2012). Effect of macro and micronutrients sprays on fruit quality and quantity of zard and rowghani olive (*Olea europaea* L.) cultivars in Northern Iran. American Eurasian Journal Agricultural and Environment Science, 12, 1548-1552.

Aydın B., Aktürk D. (2018). Energy use efficiency and economic analysis of peach and cherry production regarding good agricultural practices in Turkey: A case study in Çanakkale province. Energy, 158: 967-974.

Asgharipour M.R., Kamari F., Ramroudi M., and Alizadeh Y. (2020). Evaluation of agrobiodiversity in Ilam Province (during 2004-2016). Evaluation, 121, 132.

Bakhoda H., Almassi M., Moharamnejad N., Moghaddasi R., and Azkia M. (2012). Energy production trend in Iran and its effect on sustainable development. Renewable and Sustainable Energy Reviews, 16(2), 1335-1339.

Bayraktar M., Hayta-Smedley S., Unal S., Varol N., Gurel A. (2020). Micropropagation and prevention of hyper-hydricity in olive (*Olea europaea* L.) cultivar 'Gemlik. South African Journal of Botany, 128:264–273.

Bahamin S., Koocheki A., Nassiri Mahallati M., and Beheshti S. A. (2019). Effect of biological and chemical fertilizers of nitrogen and phosphorus on quantitative and qualitative productivity of maize under drought stress conditions. Environmental Stresses in Crop Sciences, 12(1), 123-139.

Cavaca L.A.S., López-Coca I.M., Silvero G., Afonso C.A.M. (2020). The olive-tree leaves as a source of high-added value molecules: Oleuropein. Studies in Natural Products Chemistry, 64:131–180.

Debnath S.C. (2018.) Thidiazuron in micropropagation of small fruits. In Thidiazuron: from urea derivative to plant growth regulator. Pp, 139–158.

Erdal G., Esengün K., Erdal H., and Gündüz O. (2007). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy, 32(1), 35-41.

Eren Ö., Gökdoğan O., Baran M.F. (2019). Determination of greenhouse gas emissions (GHG) in the production of different plants in Turkey. Fresenius Environmental Bulletin, 28(2A): 1158-1166.

Emami T., Mirzaeiheydari M., Maleki A. and Bazgi M., 2019. Effect of native growth promoting bacteria and commercial biofertilizers on growth and yield of wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) under salinity stress conditions. Cellular and Molecular Biology, 65(6), pp.22-27.

Ganjineh E., Babaii F., Mozafari A., Heydari M.M. and Naseri R., 2019. Effect of urea, compost, manure and bio-fertilizers on yield, percentage and composition of fatty acids of sesame seed oil (*Sesamum indicum* L.). Cellular and Molecular Biology, 65(5), pp.64-72.

Heydari M.M. and Maleki A., 2014. Effect of phosphorus sources and mycorrhizal inoculation on root colonization and phosphorus uptake of barley (*Hordeum vulgare* L.). International Journal of Current Microbiology and Applied Sciences, 3(8), pp.235-248.

Heydari M.M., Brook R.M., Withers P. and Jones D.L., 2011. Mycorrhizal infection of barley roots and its effect upon phosphorus uptake. Aspects of Applied Biology, (109), pp.137-142.

Heydar M., Mardaneh E., and Loxton, R. (2022). Approximate dynamic programming for an energy-efficient parallel machine scheduling problem. European Journal of Operational Research, 302(1), 363-380.

Fathi A., and Bahamin, S. (2018). The effect of irrigation levels and foliar application (zinc, humic acid and salicylic acid) on growth characteristics, yield and yield components of roselle (*Hibiscus sabdariffa* L.). Environmental Stresses in Crop Sciences, 11(3), 661-674.

Foladvand F., Khoshkhabar H., Naghdi N., Hosseinabadi M., Bahamin S., and Fathi A. (2017). The effect of sowing date and nitrogen on yield, and essential oil of German chamomile. Scientia, 19(3), 85-92.

Ghane Golmohamadi, F., Hosseini, R., Morad Nezhad, M. (2019). Investigating the effect of simultaneous application of red LED and sodium dikegulac on shoot regeneration and longitudinal growth of olive (*Olea europaea* L.) cv. Zard explants. *Iran J Plant Biology*, 11(1):81–96.

Ghorbani R., Mondani F., Amirmoradi S., Feizi H., Khorramdel S., Teimouri M.,. and Aghel, H. (2011). A case study of energy use and economical analysis of irrigated and dryland wheat production systems. Applied Energy, 88(1), 283-288.

Goenka S, Simon, S.R. (2021). A novel pro-melanogenic effect of standardized dry olive leaf extract on primary human melanocytes from lightly pigmented and moderately pigmented skin. Pharmaceuticals, 14(3):252.

Gökdoğan O., & Erdoğan O. (2018). Evaluation of energy balance in organic olive (*Olea europaea* L.) production in Turkey. Erwerbs-Obstbau, 60(1), 47-52.

Gökdoğan O., & Erdoğan O. (2021). Determining the Energy Use Efficiency and Greenhouse Gas Emissions (GHG) in Olive Farming. *European Journal of Science and Technology*, 23:717-724.

Gong G., Chiong R., Deng Q., Han W., Zhang L., & Huang D. (2021). Energy-efficient production scheduling through machine on/off control during preventive maintenance. Engineering Applications of Artificial Intelligence, 104, 104359.

Hemmati A., Tabatabaeefar A., Mousavi-Avval S. H., & Poozesh M. (2013). Energy flow modeling and economic analysis of olive production based on different orchard size in Guilan province of Iran. International Journal of Agriculture and Crop Sciences *(IJACS)*, 5(15), 1612-1621.

Kafkaletou M., Ouzounidou G., Tsantili E. (2021). Fruit ripening, antioxidants and oil composition in Koroneiki Olives (*Olea europaea* L.) at different maturity indices. Agronomy, 11(1):122.

Karaağaç H.A., Baran M.F., Mart D., Bolat A., Eren Ö. (2019). Nohut üretiminde enerji kullanım etkinliği ve seragazı (GHG) emisyonunun belirlenmesi (Adana ili örneği). Avrupa *B*ilim ve Teknoloji Dergisi, 16: 41-50.

Kardoni F., Bahamin S., Khalil Tahmasebi B., Ghavim-Sadati S. H., & Vahdani S. E. (2019). Yield Comparisons of Mung-bean as Affected by Its Different Nutritions (Chemical, Biological and Integration) under Tillage Systems. Journal of Crop Ecophysiology, 13(49 (1)), 87-102.

Kazemi H., Kamkar B., Lakzaei S., Badsar M., & Shahbyki M. (2015). Energy flow analysis for rice production in different geographical regions of Iran. Energy, 84, 390-396.

Khoshnevisan B., Rafiee S., Omid M., & Mousazadeh H. (2013). Comparison of GHG emissions of efficient and inefficient potato producers based on Data Envelopment Analysis. *Journal of* Agricultural Engineering and Biotechnology, 1(3), 81-88.

Liu Y., Langer V., Høgh-Jensen H., & Egelyng H. (2010). Life cycle assessment of fossil energy use and greenhouse gas emissions in Chinese pear production. Journal of Cleaner Production, 18(14), 1423-1430.

Maleki A., Pournajaf M., Naseri R., Rashnavadi R. and Heydari M., 2014. The effect of supplemental irrigation, nitrogen levels and inoculation with rhizobium bacteria on seed quality of chickpea (*Cicer arietinum* L.) under rainfed conditions. International Journal of Current Microbiology and Applied Sciences, 3(6), pp.902-909.

Mirzaei-Heydari M., 2013. The role of bio-inoculants on phosphorous relations of barley. Bangor University (United Kingdom).

Mobtaker H. G., Keyhani A., Mohammadi A., Rafiee S., & Akram A. (2010). Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. Agriculture, Ecosystems & Environment, 137(3-4), 367-372.

Mohammadi A., Tabatabaeefar A., Shahin S., Rafiee S., & Keyhani A. (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy conversion and management, 49(12), 3566-3570.

Mohammadi A., & Omid M. (2010). Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. *Applied energy*, 87(1), 191-196.

Mousavi-Avval S. H., Rafiee S., Jafari A., & Mohammadi A. (2011). Optimization of energy consumption for soybean production using Data Envelopment Analysis (DEA) approach. Applied Energy, 88(11), 3765-3772.

Nikkhah A., Emadi B., Shabanian F., & Hamzeh-Kalkenari H. (2014). Energy sensitivity analysis and greenhouse gas emissions for tea production in Guilan province. Iran, Agroecology, 6(3).

Ozkan B., Akcaoz H., & Fert C. (2004). Energy input–output analysis in Turkish agriculture. Renewable energy, 29(1), 39-51.

Perone C., Romaniello R., Leone A., Berardi A., & Tamborrino A. (2022). Towards energy efficient scheduling in the olive oil extraction industry: Comparative assessment of energy consumption in two management models. Energy Conversion and Management: X, 16, 100287.

Pishgar-Komleh S. H., Omid M., & Heidari M. D. (2013). On the study of energy use and GHG (greenhouse gas) emissions in greenhouse cucumber production in Yazd province. Energy, 59, 63-71.

Pishgar-Komleh S. H., Sefeedpari P., & Ghahderijani M. (2012). Exploring energy consumption and CO2 emission of cotton production in Iran. Journal of Renewable and Sustainable Energy, 4(3), 033115.

Rajaeifar M. A., Akram A., Ghobadian B., Rafiee S., & Heidari M. D. (2014). Energy-economic life cycle assessment (LCA) and greenhouse gas emissions analysis of olive oil production in Iran. Energy, 66, 139-149.

Rapa M., & Ciano S. (2022). A Review on Life Cycle Assessment of the Olive Oil Production. *Sustainability*, 14(2), 654.

Rezaei A., Lotfi B., Jafari M., & Bahamin S. (2015). Survey of effects of PGPR and salinity on the characteristics of Nigella leaves. *In Biological* Forum-An International Journal (Vol. 7, pp. 1085-1092).

Romaniello R., Tamborrino A., & Leone A. (2019). Use of Ultrasound and Pef Technologies Applied to the Olive Oil Extraction Process. Chemical Engineering Transactions, 75, 13-18.

Royan M., Khojastehpour M., Emadi B., & Mobtaker H. G. (2012). Investigation of energy inputs for peach production using sensitivity analysis in Iran. Energy Conversion and Management, 64, 441-446.

Servili M., Veneziani G., Taticchi A., Romaniello R., Tamborrino A., & Leone A. (2019). Low-frequency, high-power ultrasound treatment at different pressures for olive paste: Effects on olive oil yield and quality. Ultrasonics Sonochemistry, 59, 104747.

Shamsibeiranvand Z., Sadeghi Z., Khoshkhabar H., Hosseinabadi M., & Bahamin S. (2017). Survey some physiological characteristics of medicinal plant *Scrophularia striata* Boiss in Ilam province. *Scientia*, 19 (3), 62-68.

Singh H., Mishra D., & Nahar N.M. (2002). Energy use pattern in production agriculture of a typical village in arid zone, India—part I. Energy Conversion and Management, 43(16), 2275-2286.

Tabar I. B., Keyhani A., & Rafiee S. (2010). Energy balance in Iran's agronomy (1990–2006). Renewable and Sustainable Energy Reviews, 14(2), 849-855.

Tabatabaie S. M. H., Rafiee S., Keyhani A., & Heidari M. D. (2013). Energy use pattern and sensitivity analysis of energy inputs and input costs for pear production in Iran. *Renewable Energy*, 51, 7-12.

Tabatabaie, S. M. H., Rafiee, S., & Keyhani, A. (2012). Energy consumption flow and econometric models of two plum cultivars productions in Tehran province of Iran. *Energy*, 44(1), 211-216.

Tamborrino, A., Servili, M., Leone, A., Romaniello, R., Perone, C., & Veneziani, G. (2020). Partial De-Stoning of Olive Paste to Increase Olive Oil Quality, Yield, and Sustainability of the Olive Oil Extraction Process. *European Journal of Lipid Science and Technology*, *122*(11), 2000129.

Tamborrino A., Perone C., Mojaed H., RomanielloR., Berardi A., Catalano P., & Leone A. (2021). Combined Continuous Machine to Condition Olive Paste: Rheological Characterization of Olive Paste. Chemical Engineering Transactions, *87*, 283-288.

Tipi T., Cetin B., & Vardar A. (2009). An analysis of energy use and input costs for wheat production in Turkey. Journal of Food, Agriculture & Environment, 7(2), 352-356.

Wolf J., Adger W. N., Lorenzoni I., Abrahamson V., & Raine R. (2010). Social capital, individual responses to heat waves and climate change adaptation: An empirical study of two UK cities. Global Environmental Change, 20(1), 44-52.

Wei Z., Liao W., & Zhang L. (2022). Hybrid energy-efficient scheduling measures for flexible job-shop problem with variable machining speeds. Expert Systems with Applications, 197, 116785.