Agronomy Research **15**(4), 1463–1473, 2017
https://doi.org/10.15159/AR.17.003

Energy balance of sunflower production

S. Akdemir[1,*], C. Cavalaris[2] and T. Gemtos[2]

[1]Namık Kemal University, Technical Sciences Vocational School, TR 59030 Tekirdag, Turkey
[2]University of Thessaly, Department of Agriculture Crop Production and Rural Environment, Fytokou str., N. Ionia, GR-384 46 Volos, Greece
[*]Correspondence: sakdemir@nku.edu.tr

Abstract. The aim of the present study was to make an energy analysis of sunflower crop in the Trakya Region of Turkey, to evaluate the potential for using it as bioenergy source. Actual data for the common cropping practices applied in the region were collected with questionnaires given to the farmers. Literature data were used to obtain necessary energy indices. The collected information was used to establish energy budgets. Two alternative scenarios were examined: 1st- using only the seed for biofuel production and 2nd -using the seed for biofuel and the stalks as biomass for bioenergy. The results showed that sunflower presented positive energy balance for both cases. Net energy was 35,334 MJ ha^{-1} when only the seed was taken into account and 87,308 MJ ha^{-1} for both seed and stalks. Energy efficiency was 3.67 and 7.34 respectively. Fertilization was the most energy intensive input (6,594 MJ ha^{-1}) accounting for 48–50% of the total inputs. Tillage was the second most energy intensive input (3,595 MJ ha^{-1}) accounting for 26–27% of total inputs. There were 6 different tillage operations such as ploughing, 4 machinery passages for seedbed preparation and hoeing in the sunflower production. All these operations increased energy inputs of the tillage. The total energy inputs were relatively low because it was possible to achieve high yields without irrigation.

Key words: sunflower, energy analysis, Trakya Region.

INTRODUCTION

Energy analysis is an important tool to evaluate the energy efficiency of production systems. In agriculture, it can offer an in depth knowledge of the energy flows and can reveal more energy efficient cropping practices. It is therefore important to make the analysis of the existing systems as a basis to improve their efficiency. There is no standard methodology established for this analysis. It is generally difficult to analyse different management options because of the complexity of the production systems and the lack of specific parameters for each case. For that reason a more general approach is followed most of the times using literature data from wider areas. Erdogan (2009), developed an internet based software, namely AgrEN_I/O v 1. 0 Beta, for energy input-output analyses for crop production. As an example, the software was run for a maize crop production in the Cukurova region. Energy equivalent of total input, yield, other output were determined as 28,090.71 MJ ha^{-1}, 132,300 MJ ha^{-1} for 9 t ha^{-1} seed yield and 187,416 MJ ha^{-1}for 49.32 t ha^{-1} other output. Energy ratio was calculated as 11.58 for Cukurova Region of Turkey. Romanelli & Milan (2005) aimed to develop a methodology that would support the development of a model using a spreadsheet, and use it to analyse the energy balance of production systems. The model was applied to a traditional production system of maize (*Zea mays* L.) silage and a Bermuda grass (*Cynodon* spp.) haylage. The gross energy balance presented was 14.1 energy units of output per energy input for maize silage and 0.98 for haylage. For the digestible energy balance, the values were 9.1 and –0.99, respectively. The best alternative scenarios for improving energy efficiency in maize silage and haylage production were the reduction of fertilizer rates and irrigation use (Romanelli & Milan, 2005).

Azarpour (2012) determined energy efficiency (energy output to input ratio) for winter wheat seed and straw to be 2.47 and 2.48, respectively, showing the effective use of energy in wheat production. Energy balance efficiency (production energy to consumption energy) for seed and straw was calculated 1.50 and 1.29, respectively. Arin & Akdemir (1987) determined energy consumption per unit area in dry onion production. Total input was determined as 41,665 MJ ha^{-1} and the output was 25,050 MJ ha^{-1}. Arin et al. (1988) also determined agricultural inputs and outputs for wheat, sunflower, rice and onion production. They calculated energy inputs per kg produced. Energy use was 5.93 MJ kg^{-1} of wheat, 6.34 MJ kg^{-1} of sunflower, 5.36 MJ kg^{-1} of rice.

Gemtos et al. (2013) carried out a research in Thessaly, Central Greece to assess the potential of using irrigated sunflower, rain fed rapeseed and irrigated sweet sorghum as energy crops. They produced energy analysis taking into account as output either only for the seed or including the stalks as well. Their results showed that the energy balances were positive. The overall results gave maximum energy efficiency coefficients of 2.89 without the stalks and 6.16 with stalks. Analysis of the inputs showed that energy for irrigation was the most energy intensive input in the irrigated crops while nitrogen fertilisation was the rain fed rapeseed.

Baran & Karaağac (2014) studied the energy balance in sunflower as second crop in a year. The results showed that energy output/input rate was 3.21, the specific energy value was 8.19 MJ kg^{-1} and the net energy was 34,404 MJ ha^{-1}. Another study by Baran & Gökdoğan (2014) determined the energy balance in watermelon and melon production in Kirklareli province. Energy output/input ratio, specific energy, and energy productivity of watermelon were determined at 4.74, 0.40 MJ kg^{-1}, and 2.49 kg MJ^{-1} respectively. The energy output/input ratio, specific energy and energy productivity of melon were determined at 2.97, 0.63 MJ kg^{-1}, and 1.56 kg MJ^{-1} respectively. Fertilizers had the highest contribution to the energy inputs and were followed by fuel and human energy consumption. Dilay et al. (2010) studied Karaman apple (Malus communis L.) production and determined the energy balance. According to their findings energy use efficiency was estimated as 2.33 MJ kg^{-1}. Gokdogan (2011) determined energy output/input ratio in peach production as 1.52 and energy productivity at 0.80 kg MJ^{-1}.

Sunflower as energy and oil crop is very important for Turkey and Greece. It is widely produced in Trakya Region of Turkey. Sunflower was planted in 720,108 ha, with total production of 1,670,000 tonnes and yield of 2,320 kg ha^{-1} in 2016. Due to the importance of the crop, sunflower energy balance were analysed by TUIK (2017). Energy crops have been produced in Greece and Turkey because their profitability is higher than cereals. Governments give support for growing energy crops. The aim of the present study was to make energy analysis for sunflower crop in Trakya region and to investigate the potential to use it as an energy crop.

MATERIALS AND METHODS

The common cropping practices in sunflower production at the region of Trakya are shown in Table 1. The data about field operations, speed, time, man power, agricultural machinery size, etc. were obtained from a big local farm which has 6,045 ha production area including different size parcels for sunflower production. In addition production data obtained from Kirklareli Soil, Water Agrometeorology Research Institute. The data were collected from three main cultivation areas of Trakya: Tekirdağ, Edirne and Kirklareli that cultivated 300,226 ha with total annual production of 682,583 tonnes of seed (Table 2). The data are for 2015 which was a typical year for sunflower production. In this research conventional farming practices that are widely used in Trakya Region were taken into account to establish the energy budget. A general production model was assumed to determine agricultural inputs.

The boundary of the system was assumed to be the 'Farm gate'. One hectare was used as functional unit for all the estimations.

Table 1. Summary records of cultivation practices for sunflower

	Starting time	Ending time	Type of the Input	Amount of the Input
Ploughing	September	November		
Cultivator	March	March		
Cultivator	April	April		
Toothed harrow	April	April		
Sowing	April	May		
Row spacing			cm	70
Sowing rate			Number Seeds ha^{-1}	40,000–55,000
Sowing rate			kg ha^{-1}	3–3,5
Fertiliser application kg ha^{-1}	April	April	20-20-0(N-P-K)	200–250
			Ammonium nitrate	110–130
Sprayer (Herbicide) kg ha^{-1}	April	April	Pendimethalyn	3.11
			Prometryne	3.32
Toothed harrow	April	May		
Rolling cylinder	April	May		
Fertiliser spreader	June	June		
Hoeing machine	June	June		
Sprayer	June	June		
Combine harvester	August	September		

Table 2. Trakya region sunflower production (TUIK, 2017)

Region	Harvested area (ha)	Production (ton)	Seed yield (fresh weight) (kg ha^{-1})
Tekirdağ	128,468	267,012	2,078
Edirne	98,406	226,573	2,302
Kırklareli	73,352	188,998	2,577
Total/Average	300,226	682,583	2,319

Energy inputs estimation

The energy analysis was mainly based on a methodology developed by the Laboratory of Farm Mechanisation of the University of Thessaly (Gemtos et al., 2013).

There are three main paths of energy inflow in the field. The first path is the solar energy. This is captivated by the plants during the photosynthesis process. As it is provided for free, it is not considered to the energy inputs and this is the reason why, contrary to other energy transformation processes, in agriculture the energy budget is usually positive. The second path, is direct energy consumed in the farm for field operations such as tillage, sowing, and irrigation etc. This path uses mainly fuel, lubricants and human labour as energy inputs. The third path is indirect energy that is consumed outside the farm boundaries to produce any input (machinery, chemicals) used in farm. In that case, any material brought into the farm is considered as 'energy input' (Tables 3 & 5) embodying all the energy included in raw materials as well as the energy sequestered for manufacturing, transportation and commodity uses.

Energy 'outputs' were considered all agricultural goods produced in the field and sold to the 'market'. According to the energy inputs and outputs, energy budgets for sunflower crop were estimated. Direct and indirect energy consumption was estimated for the inputs shown in Table 1 as described below.

Machinery inputs

Machinery inputs include direct energy use for the operation of the machinery in the field (fuel, lubricants and human labour) and indirect energy as the energy sequestered in the materials of the machinery. Indirect energy was estimated as the energy sequestered to the tractor and the machinery during manufacturing as well as the energy added to them during their estimated life for repairs and maintenance. The manufacturing energy was estimated as the sum of the energy used for the raw materials production and the energy for the machinery construction (Bowers, 1992). The energy estimated to be spent for transportation and handling of the machinery was also added at 8.8 MJ kg^{-1} (Bowers, 1992). The energy spent for repair and maintenance during the life of the machine was estimated as a percentage of the energy spent to produce the machinery, using the Coefficients for Repair and Maintenance (CRM) (Bowers, 1992). The total sequestered energy (manufacturing and repairs/maintenance) was then divided by the estimated working life of the machinery to estimate the hourly energy input and then by the field performance (estimated from the working width, the travel speed and the field efficiency) for each operation to find the energy spent per ha (Table 3). For all the operations two tractors were assumed to be used. A 4 WD tractor for the heavy field operations like tillage and transportation and a 2WD tractor to carry out the lighter operations like sowing, spraying and fertilization. This represents the common practice for the region under study.

For the direct energy, fuel consumption and lubricants had to be added. Human energy is a very small in today's mechanised agriculture and therefore, it was not included in the calculations. Fuel consumption (L ha^{-1}) was estimated from the research conducted retrieving empirical values from the farmers of Trakya (Table 4). Fuel consumption was then converted to energy by using the energy content of the fuel (38.66 MJ L^{-1}) and the production and handling energy (9.12 MJ L^{-1}), giving total energy content of 47.78 MJ L^{-1} (Pimentel, 1992). This was equal to 57.57 MJ kg^{-1}, if 0.83 t m^{-3} density was taken into account. The consumed energy by lubricants was taken at 4% of the fuel energy (Fluck, 1992). The sum of fuel and lubricant energy was the total direct energy inputs (Table 4).

Table 3. Indirect energy consumption for field operations

-	Weight kg	ME(1) MJ kg^{-1}	Working width m	Working speed (u) m s^{-1}	fe(2)	Field performance (fp) ha h^{-1}	Estimated Life (LE) hours	c_{RM}(3)	Indirect Energy Implement MJ ha^{-1}	Tractor	Total
Main Tractor 4WD	4,200	86.8					16,000	0.49			
Secondary Tractor2WD	2,520	86.8					12,000	0.49			
Tillage implements											
Ploughing	500	52.8	1.4	6.00	0.85	0.71	2,000	0.97	39.5	50.8	90.3
Cultivator (1st)	370	52.8	3.4	9.00	0.85	2.60	2,000	0.51	6.3	13.9	20.2
Cultivator (2nd)	370	52.8	3.4	9.00	0.85	2.60	2,000	0.51	6.3	13.9	20.2
Toothed harrow	170	52.8	4	15.00	0.85	5.10	2,000	0.61	1.6	5.7	7.2
Rolling cylinder	650	52.8	5	12.00	0.80	4.80	2,000	0.61	6.3	6.0	12.4
Hoeing machine	230	52.8	3.75	7.00	0.85	2.23	2,000	0.51	4.6	16.2	20.8
Other implements											
Row crop seeder	400	56.9	3	7.10	0.65	1.38	1,500	0.43	17.4	1.4	18.8
Sprayer	130	56.9	16	14.00	0.65	14.56	1,500	0.37	0.5	2.0	2.5
Fertilizer spreader	150	52.8	16	14.00	0.70	15.68	1,200	0.49	0.7	1.8	2.5
Sunflower picker	7,000	86.8	3.75	4.0	0.65	1.0	2,000	0.24	417.8		417.8
Harvesting											
Combine harvester	7,700	86.8	5.6	5.0	0.65	1.82	2000	0.24			246.2

(1)ME = Manufacturing energy (Batty & Keller 1980; Bowers 1992); (2) fe = field efficiency (ASABE D497.4)
(3)cRM = coefficient used to estimate the energy sequestered in repairs and maintenance (Bowers 1992); * kg per ha was estimated for the pipelines weight.

Table 4. Direct energy consumption for field operations

	Fuel consumption (FC) (l ha^{-1})	Direct energy (E_V) MJ ha^{-1}
Tillage implements		
Ploughing	29.90	1,486
Cultivating (1st pass)	9.85	489
Cultivating (2nd pass)	7.80	388
Tooth harrowing	3.95	196
Rolling cylinder	4.50	223
Hoeing	8.80	437
Other implements		
Sowing	7.05	350
Spraying	3.60	17
Fertilizer application	3.45	16
Harvesting	14.6	1,117

Consumable goods

Consumable goods were used in several stages of crop growth. For most of them energy sequestered values was found in the literature. The values and the sources are shown in Table 5. Helsel (1992) estimated the total energy of the N fertilizer at 69.5 GJ t^{-1} for production, 2.6 GJ t^{-1} for packaging, 4.5 GJ t^{-1} for transportation and 1.6 GJ t^{-1} for the application. Energy values for pesticides were also taken from the literature.

Table 5. Consumable goods energy consumption

Consumable goods	Energy content (MJ kg^{-1})	Source
Fertilisers		
N	78.1	Helsel (1992)
P_2O_5	17.0	Helsel (1992)
K_20	13.7	Helsel (1992)
Sunflower Seeds	26.3	Kalivrousis et al.(2002)
Herbicides		
Pendimethalyn	461	Heichel (1980)
Prometryne	461	

Energy consumed for transportation

A platform weighing 900 kg was used to transport the final products to the storage facilities. The payload was 5,000 kg. The energy sequestered for manufacturing was taken at 52.78 MJ kg^{-1} plus 8.8 MJ kg^{-1} for transportation and handling (Fluck, 1992) giving an initial energy for the platform of 55,422 MJ. For repair and maintenance a coefficient 0.8 of the manufacturing energy was used or 38,001 MJ. Total indirect energy for the platform was then 93,423.6 MJ and for the 82 kW tractor, which towed this platform, was 347,980 MJ. Working life of the platform was 3,000 h and of the tractor 16,000 hours (ASABE 2007 Standards). As such, the energy per hour was 31.14 MJ h^{-1} for the platform and 21.75 MJ h^{-1} for the tractor. With an average transportation speed at 20 km h^{-1} and travelling distance 10 km (5+5 km) and delivery efficiency of 0.6 the travelling time was 0.83 h, the work rate 6 t h^{-1} and the fixed energy was 0.0052 MJ kg^{-1} for the platform, 0.0036 MJ kg^{-1} for the tractor and the total 0.0088 MJ kg^{-1} of transported material. The direct energy consumption was estimated by considering the value given for trucks by Fluck (1992), 0.0018 MJ kg^{-1} km^{-1}.

Harvesting energy

Indirect energy inputs derived from the use of the harvesting machinery were estimated as described earlier (Table 3). Direct energy was estimated by literature data (Leach, 1976) (Table 4).

Energy output estimation

The sunflower production (seed) from three main cultivation areas from Trakya was taken into account (Table 2). Considering an average of 15% of seed moisture content during harvesting, seed weigh was converted to dry seed weight. Apart from the seed, the stalks were also considered as potential output. Field measurements in Greece by Gemtos et al. (2013) gave dry stalk/seed ratio of 1.23. Multiplying the dry seed yield by 1.23 gave an estimation of stalk yields for Trakya Region. The authors also considered energy content for seed at 25.55 MJ kg^{-1} and for stalks 17.3 MJ kg^{-1}. These values were taken into account to estimate the seed and stalk energy outputs in the present study.

Energy efficiency estimation

Three indices were used for the energy efficiency estimation. The net energy which was the energy output minus the energy input measured in MJ. The energy efficiency coefficient was obtained by dividing the energy output by the energy input, which was a dimensionless number. Finally, the energy productivity was the energy spent per kg of output measured in kg MJ^{-1}.

RESULTS AND DISCUSSION

Table 6 shows an analysis of the energy inputs for the sunflower production. Ploughing was among the most intensive field operations and accounted for 1,576 MJ ha^{-1}, almost half of the total energy spent for tillage operations. In tillage operations, the most energy intensive input was the direct energy used for the fuel (3,416 MJ ha^{-1} compared to indirect inputs of 178 MJ ha^{-1}). For sowing, the most important input comes from the use of the sowing machine (388.75 MJ ha^{-1} compared to 85.48 MJ ha^{-1} for the seed). Regarding fertilisation, the most important were the indirect inputs coming from the use of fertilizers (6,557 MJ ha^{-1}) and especially nitrogen (5,837 MJ ha^{-1}) which was the higher energy demanding commodity to be used.

The use of pesticides was another indirect energy input accounting for 1,404 MJ ha^{-1}. Harvesting contributed to the energy balance with significant amounts of direct and indirect energy inputs. For the combine harvester it was estimated that a total of 1,116 MJ ha^{-1} was consumed while for the round baler, in the case of stalk harvesting, another 469 MJ ha^{-1} were required. Finally, transportation contributed a small amount to the energy inputs with 46 MJ ha^{-1} for only the seed and 95 MJ ha^{-1} for both seed and stalks. It is important however to mention that it is crucial to have well established regional network of biomass use plants in order to keep short travel distance for the product otherwise the energy inputs could be significantly increased. Concluding indirect energy inputs related with the use of agricultural equipment accounted for

753 MJ ha^{-1} (5.5% of total inputs), direct energy inputs for machinery use accounted for 4,522 MJ ha^{-1} (32.8% of total inputs) giving a total machinery input (direct and indirect) of 5,275 MJ ha^{-1} (42.2% of the total inputs). Additionally direct energy inputs related to the use of the consumable goods (fertilizers, pesticides, seeds etc.) accounted for 7,961 MJ ha^{-1} (57.8% of total inputs). The total inputs for sunflower production (machinery and consumable goods) were estimated at 13,768 MJ ha^{-1}. In a similar study in Greece, Kalivrousis et al. (2001) have found that the total energy inputs for sunflower production were 10,490 MJ ha^{-1}. The difference is mainly owed to almost half energy consumption for soil tillage in their research. Indeed the authors accounted for three tillage operations to prepare the seedbed while for the region of Turkish Trakya the common practice was five or more operations.

Table 6. Summary of machinery and consumable goods inputs

	Machinery Energy Inputs (MJ ha^{-1})	Energy of Consumable Goods (MJ ha^{-1})	Total (MJ ha^{-1})
Tillage			
Ploughing	1,576		1,576
Cultivating (1st pass)	510		510
Cultivating (2nd pass)	409		409
Harrowing	407		407
Rolling cylinder	236		236
Hoeing	458		458
Total	3,595		3,595
Sowing			
Seed		85	85
Sowing	389		389
Total			474
Fertilizer application			
Nitrogen		5,837	5,837
Phosphorus		720	720
Application	37.4		37
Total		6,557	6,594
Pesticide application			
Pendimethalyn		519	519
Prometryne		886	886
Application	19.4		19
Total		1,405	1,424
Harvesting			
Combine harvester	1,117		1,117
Round baler	469		469
Total	1,585		1,585
Transportation			
Total	95		95
Total Energy Inputs	5,275	7,961	13,768

Table 7 shows the energy budgets for the sunflower production for the two alternative scenarios. The first one for using only the seed for bioenergy production while the stalks remain in the field and the second for using both seed and stalks as a bioenergy stock material. On both scenarios, crop fertilization was the most energy intensive input and required (6,594 MJ ha^{-1}) accounting for 48-50% of the total inputs. This is also in agreement with the findings by Kalivrousis et al. (2001). From that point of view, improving industry efficiency for the nitrogen fertiliser production and promoting practices for increasing Nitrogen Use Efficiency (NUE) will significantly improve energy efficiency of the crop (Romanelli and Milan, 2005). Soil tillage was the second most energy intensive input (3,595 MJ ha^{-1}) accounting for 26–27% of total energy inputs. The promotion of conservation agriculture practices and the exclusion of ploughing can offer significant energy savings as well as environmental benefits (Cavalaris et al., 2008). Pesticides use accounted for 1,424 MJ ha^{-1} that represented 10–11% of total inputs. Harvesting consumed 1,117 MJ ha^{-1} when using only the seed and reached 1,585 MJ ha^{-1} when harvesting the stalks as well. It represented 8% and 12% of the total energy inputs respectively. Sowing required 474 MJ ha^{-1} which was 3–4% of the total inputs and the minimum requirements was for transportation to a distance up to 5 km (41 MJ ha^{-1} for only the seed and 95 MJ ha^{-1} for the both seed and stalks). It is important to mention that on a similar research carried out by Gemtos et al. (2013) in the region of Thessaly, central Greece, the most energy intensive input was irrigation that accounted for over 50% of the total inputs. On another study, Cavalaris et al. (2008) showed that irrigation in sunflower reached 34,784 MJ ha^{-1} (71% of the total inputs) when the water was pumped from deep aquifers (> 100 m). This is an important advantage for the Trakya region as the crop can be cultivated as rain fed with yields over 2,000 kg ha^{-1}.

Table 7. Energy budgets for the sunflower production in the region of Trakya

Energy Budget Energy Inputs (MJ ha^{-1})	Without the stalks	With the stalks
Tillage	3,595	3,595
Sowing	474	474
Fertilization	6,594	6,594
Pesticide application	1,424	1,424
Harvest	1,117	1,585
Transportation	41	95
Total	13,244	13,768
Yield (dry matter kg ha^{-1})		
Seed	2,020	2,020
Stalks		3,035
Energy Outputs (MJ ha^{-1})		
Seed	48,578	48,578
Stalks		52,498
Total	48,578	101,076
Energy Budget		
Net Energy (MJ ha^{-1})	35,334	87,308
Energy Efficiency	3.67	7.34
Energy Productivity (kg MJ^{-1})	0.15	0.37

The average sunflower seed yield for the studied region in 2015 was 2,320 kg ha^{-1}. The total energy outputs for seed was 30,852 MJ ha^{-1} derived from the oil and 17,727 MJ ha^{-1} derived from the cake. This made a total of 48,578MJ ha^{-1}. If the stalks would also be utilized another 52,498 MJ ha^{-1} could be obtained. In that case the total outputs reached 101,076 MJ ha^{-1}. With a total energy input of 13,244 MJ ha^{-1} in the first scenario and 13,768 MJ ha^{-1} in the second, a net energy balance of 35,334 MJ ha^{-1} and 87,308 MJ ha^{-1} respectively was obtained. Energy efficiency coefficients were 3.67 and 7.34 and energy productivity 0.15 kg MJ^{-1} and 0.37 kg MJ^{-1} respectively. Kalivrousis et al. (2002) reported energy efficiency of 4.5 for dry land sunflower production in Greece and Cavalaris et al. (2008) reported energy efficiency of 3.81 for irrigated sunflower. As these studies were carried out in a similar climate they are indicators of the potential to use sunflower as an energy crop in the region. It definitely presents an advantage compared with other dry land crops like wheat which presented coefficient of energy efficiency 2.47 (Azarpoor, 2012).

From the presented results it is definite that in both cases the energy budgets are positive, even if only the seed is utilized but the gains could be doubled if also the stalks can be used. According to the Turkish Statistic Institute, in Turkey the total planted area for sunflower is 615,349 ha (TUIK, 2017). With an average seed yield of 2,440 kg ha^{-1} it results in an annual production of approximately 1,500,000 tonnes per year (TUIK 2017). Sunflower oil, cake and stalk may be used as energy sources. Annual sunflower seed production was 1,500,000 tonnes in 615,349 hectares for 2016 in Turkey. Stalk/seed ratio was assumed as 1.23. This means that there is an annual production of 1,843,000 tonnes of stalks. Energy content of the stalks was 17.3 MJ kg^{-1}. Potential energy for sunflower was calculated as 31,918,500 GJ per year. Total harvested area was 300,225 hectares and seed production was 682,583 tonnes in Trakya Region for 2016 (TUIK, 2017). Energy potential from stalk would be 14,540.445 MJ per year. Sunflower seeds can be used for biodiesel production. But Turkey imports sunflower and other oils for food. Decreasing of petroleum prices and additional taxes decreased biodiesel production of Turkey even though there are many companies with license to produce biodiesel. There is also a potential to use sunflower cakes for animal feedstuff and stalks as biomass energy production.

The removal however of the whole plant material from the field is an issue that requires further investigation. Leaving the soil bare, without any crop residues returned into it, could lead to soil degradation problems such as soil erosion, loss of soil organic matter and large amounts of nutrients removed from the soil and should be replaced by additional fertilizers. In that case, alternative cropping systems should be developed using winter cover crops most probably mixtures of cereals and legumes to protect the soil and add organic matter and nutrients to replace the removed stalks.

CONCLUSIONS

From the presented results the following conclusions can be drawn:

1) Sunflower as an energy crop shows good adaptation to the climatic conditions of the Trakya region where no irrigation is required. It presents positive energy balance. Therefore, it is a suitable energy crop candidate for the region.

2) Fertilization was the most energy intensive input in sunflower production at the Trakya region and soil tillage by using mouldboard plough was the second one.

3) The use of the crop residues improves significant the energy balance.

4) The energy efficiency was 3.67 when only the seed is used and increased to 7.34 when the stalks were included.

REFERENCES

ASABE. 2007. Standards. Agricultural machinery management (D496.3 Feb.2006) and Agricultural machinery management data (D797.4) and (D497.5) p 356 & 362. *American Society of Agricultural Engineers*, St Joseph. Michigan, USA.

Arın, S. & Akdemir, B. 1987. Investigation of energy balance for mechanization of onion production in Tekirdağ 3rd International Symposium on mechanization and energy in Agriculture, 28–29/10/1987, İzmir, Turkey, 195–201.

Arın, S., Akdemir, B. & Kayışoğlu, B. 1988. Establishment of energy balance in crop production in Trakya region. Tarımsal Mekanizasyon 11. Ulusal Kongresi, A.Ü. Ziraat Fakültesi tarımsal Mekanizasyon Bölümü, Bildiri Kitabı, S. 124–135, ERZURUM

Azarpour, E. 2012. Determınation of Energy Balance And Energy Indices in Wheat Production Under Watered Farming in North of Iran. *ARPN Journal of Agricultural and Biological Science* **7**(4), 250–255.

Baran, M.F. & Gökdoğan, O. 2014. Energy Input-Output Analysis In Watermelon And Melon Production: A Case Study For Kirklareli Province. Anadolu. *J Agr Sci*. **29**(3), 217–224.

Baran, M.F. & Karaağaç, H.A. 2014. Determination of Energy Usage Efficiency in Second Crop Sunflower Production in Kırklareli Province. *Türk Tarım ve Doğa Bilimleri Dergisi* **1**(2), 117–123.

Bowers, W. 1992. Agricultural field equipment. In: Fluck, R.C. (ed.) *Energy in Farm Production*. Vol. **6** in Energy in World Agriculture. Elsevier, New York. pp. 117–129.

Cavalaris, C., Karamoutis, C. Fountas, S. & Gemtos, T.A. 2008. Sunflower oil energy budget for in-farm production under four tillage systems. *Eurageng 2008 World Congress Crete*.

Dilay, Y., Özkan, A. & Aydın, C. 2010. Energy Analysis of Apple Productions in Karaman and Determination of the Efficiency of Energy Use, 26. *Tarımsal Mekanizasyon Ulusal Kongresi, 22–23 Eylül 2010*, Hatay, Proceedings book: 400–405.

Erdoğan, Y. 2009. *Developing an internet based software for the energy input-output analyses ın crop production*, Department of Agicultural Machinery Institute of Natural And Applied Sciences Unıversity of Çukurova

Gemtos, T.A. 1992. Production of crop residues in Greece and their use for energy production. *Scientific Issue of TEI Pireus* 1992, No **1**. (in Greek).

Gemtos, T.A., Cavalaris, C., Karamoutis, C., Tagarakis, A. & Fountas, S. 2013. Energy analysis of three energy crops in Greece, Agric Eng Int: *CIGR Journal* **15**(4), 52–66.

Fluck, R.C. 1992. Energy of Human Labor In: Fluck, R.C. (ed.) *Energy in Farm Production.* Vol. 6 in Energy in World Agriculture. Elsevier, New York, pp. 31–38.

Gokdogan, O. 2011. Energy Input Output Analysıs In Peach Agrıculture In Isparta Province, *EÜFBED – Fen Bilimleri Enstitüsü Dergisi Cilt-Sayı* **4–2**, 145–155.

Helsel, Z.R. 1992. Energy and alternatives for fertilizer and pesticide use In: Fluck, R.C. (ed.) *Energy in Farm Production*. Vol. **6**, Energy in World Agriculture. Elsevier, N.Y., pp. 177–201.

Heichel, G.H. 1980. Assessing the fossil energy costs of propagating agricultural crops. In: D. Pimentel (Editor), *Handbook of Energy Utilization in Agriculture*, Boca Raton, Fl: CRC Press. pp 27–33.

Kalivrousis, L., Natsis, A. & Papadakis, G. 2002. The Energy balance of sunflower production for biodiesel in Greece. *Biosystems Engineering* **81**(3), 347–354.

Leach, G. 1976. Energy and Food Production. IPC Scinece and Technology Press, U.K.

Lide, D.L. 1991 Handbook of Chemistry and Physics. 71st Ed, CRC.

Pimentel, D. 1992. Energy inputs in production agriculture. In: R.C. Fluck (Editor), *Energy in Farm Production*. Energy in world agriculture, **6**. Elsevier, Amst., pp.13–29.

TUIK (Turkish Statistical Institute), 2017. Crop production statistics, https://biruni.tuik.gov.tr/bitkiselapp/bitkisel_ing.zul (access date: 01.02.2017)