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Energy Balance for Production of Selected Crops in Turkey

Türkiye'de Seçilmiş Bitkilerin Üretiminde Enerji Bilançosu

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ABSTRACT

The main purpose of this study was to analyze the energy input, energy output and energy output/input ratio of four selected crops (sugar beet, wheat, sunflower and maize) during 2017 and 2018 cultivation seasons in Turkey. The data were determined by a questionnaire applied to 140 farms in 25 regions according to the stratified sampling method. The results showed that the highest average energy input was 65389.32 MJ ha^{-1} for sugar beet and least was 24595.23 MJ ha^{-1} for wheat. In these data, the highest energy requirements were found for seedbed preparation, harvesting and hoeing respectively. Average energy use efficiency varied from 16.49, 2.84, 2.36 and 4.28 for sugar beet, wheat, sunflower and maize respectively. It was found that the highest direct energy input was 44.31% for sugar beet. The non-renewable form of energy input was determined about 85.98-89.67% of the total energy input. In the light of these results; it can be said that methods such as applying new soil processing systems in large agricultural areas, introducing different agricultural and alternative fertilizer usage methods, planning in irrigation properly, switching to new irrigation methods and spreading the use of alternative energy sources in agriculture are important factors in reducing energy consumption and usage in agriculture.

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ÖZET

Bu çalışmanın temel amacı, Türkiye'de 2017 ve 2018 ekim sezonlarında seçilen dört mahsulün (şeker pancarı, buğday, ayçiçeği ve mısır) enerji girdisi, enerji çıktısı ve enerji çıktı/girdi oranını analiz etmektir. Veriler, tabakalı örnekleme yöntemine göre 25 bölgede 140 çiftliğe uygulanan anket ile belirlenmiştir. Sonuçlar, ortalama enerji girdisinin şeker pancarı için 65389.32 MJ ha^{-1} ile en yüksek ve buğday için 24595.23 MJ ha^{-1} ile en düşük olduğunu göstermiştir. Bu verilerde en yüksek enerji ihtiyacı sırasıyla tohum yatağı hazırlama, hasat ve çapalama için bulunmuştur. Ortalama enerji kullanım verimliliği şeker pancarı, buğday, ayçiçeği ve mısır için sırasıyla 16.49, 2.84, 2.36 ve 4.28 arasında değişmiştir. Direkt enerji girdisinin % 44,31 ile şeker pancarında en yüksek olduğu tespit edilmiştir. Yenilenemez enerji girdisinin toplam enerji girdisinin yaklaşık olarak % 85.98-89.67'si olduğu belirlenmiştir. Bu sonuçlar ışığında; Geniş tarım alanlarında yeni toprak işleme sistemlerinin uygulanması, farklı tarımsal ve alternatif gübre kullanım yöntemlerinin tanıtılması, sulamada doğru planlama, yeni sulama yöntemlerine geçiş ve tarımda alternatif enerji kaynaklarının kullanımının yaygınlaştırılması gibi yöntemlerin tarımda enerji tüketimini ve kullanımını azaltmada önemli faktörler olduğu söylenebilir.

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1. INTRODUCTION

The rapid growth of the world economy and population are leading to big increases in energy demand. Today, as the importance of sustainable development is increasingly understood, the efforts to the value of energy efficiency are also rising. For this reason, the development of energy efficiency at all stages, the prevention of unconscious use and waste, and the reduction of energy intensity in all sectors are the primary components of energy policies. The efficient use of energy in the agricultural sector also has very direct effects on production costs. Tipi *et al.* (2009) indicated that agriculture had a relatively larger share in the total output and employment than what it was in other sectors.

The energy required in agricultural process is mainly divided into two sub-categories: direct energy and indirect energy. Direct energy refers to the energy sources, which are directly used in the operations and processes related to agricultural production in the field, such as fuel and electricity (Hulsbergen *et al.* 2001). On the other hand, indirect energy refers to those which are not used as direct energy sources in agriculture, but used to increase the quality of agricultural production. Fertilizers, seeds, chemicals and other labors can be shown as the indirect energy sources. Also, energy may be grouped as physical, chemical and biological energy.

Alluvione *et al.* (2011) evaluated the energy requirements of maize, wheat and soybean in Italian conditions. This study highlights the energy flows of three crops rotation of three different cropping systems such as; low-input integrated farming, integrated farming and conventional farming. They found that integrated farming techniques improved energy efficiency by reducing energy inputs without affecting energy outputs. Strnad and Misa, (2016) studied the energy input–output of wheat and barley cultivation in Czech Republic. They found that the energy ratio was 8.65 for wheat and 8.63 for barley cultivation. Shahgholi *et al.* (2018) analyzed the work efficiency balance for producing sugar beet. They reported that the energy output-input ratio was 13.8, the major energy consumers were chemical fertilizers (34%) and irrigation (22%). Memon *et al.* (2012) studied the work efficiency and energy consumption of alternative production systems for producing maize. As a result of this study, the most suitable system, which resulted in the highest yield with the lowest energy consumption, was determined.

The livelihood of agriculture, the amount of cultivated area and the level of mechanization are the main factors determining the amount of energy use in agriculture (Özgöz *et al.* 2017). Mohammadi and Omid, (2010) indicated that the amount of energy used in agricultural production, processing and distribution was significantly high. A sufficient supply of the right amount of energy and its effective and efficient usage are important to be able to improve the agricultural production. When the developed countries in the world are examined in particular, agricultural production increases and direct energy use decreases in agriculture (Gellings and Parmenter, 2001). However, in 25% of EU countries, energy efficiency in agriculture is still low (Kempen and Kraenzlein, 2008). The renewable energy usage has been increasing in agriculture day by day until the beginning of 2000 (Beckman et al. 2013; Abdul Rahman et al. 2017; Miranowski, 2016).

Worldwide, cropland per capita has declined 20% during the past decade. During the same period, more than 100 million hectares of cropland have been degraded and lost due to the wind and water erosion. In the arid regions, farmers must use irrigation water. However, available irrigated cropland per capita has declined about 10% during the past decade due to the effects of population growth, salinization, water logging, and depletion of ground water resources (Pimentel, 2009). Although the renewable energy is insufficient to meet requirements, scientists claim that renewable energy sources will increasingly become important alternatives to replace the gradually declining fossil fuels.

The purpose of this study is to define the energy balance for sugar beet, wheat, sunflower and maize productions in Turkey, which are the most important means of livelihood in terms of macro and micro terms. Although all sorts of energy resources are used as input for crop production, the output of these crops is still low. If economic, sustainable development and change are considered in agricultural production, firstly energy input must be reduced or used optimally, and agricultural output should be increased. Therefore, the assessment of energy consumption for crop production is required to understand the current situation related to usage of energy resources.

2. MATERIALS AND METHODS

Although Turkey (36°-42° N - 26°-45° E) is located in a geographical area where climatic conditions are quite temperate, the diverse nature of the landscape and especially presence of the mountains extending parallel to the coasts cause the climatic conditions to differ significantly from one region to another. While the coastal regions of the country enjoy milder climates, the inland Anatolia plateau experiences hot summers and cold winters with limited precipitation (Climate, 2018). Due to irregular topography, different climates are experienced in different regions of Turkey.

Figure 1. Sugar beet growing areas in Turkey (Tuğrul et al. 2012)

Agricultural operations and the energy input and output values of field crops cultivated in these regions were determined from a questionnaire given to farmers from 66 villages selected due to their regional properties. The evaluation data are based on the survey studies that Türkşeker regularly conducts every year to determine the next year's beet purchase price. Accordingly, the data obtained from the surveys conducted in 140 farmers in 25 regions according to the stratified sampling method for sugar beet and competing products in the 2017-2018 production season were evaluated (Karagölge and Peker, 2002; Turkseker, 2017-2018) (Figure 1). The 25 sugar factories in mentioned are separated into three regions according to their geographical location and their climate characteristics. The first region has the subtropical marine climate and covers the Alpullu, Susurluk and Çarşamba sugar factories. The second has the subtropical land climate and covers the Afyon, Ankara, Bor, Burdur, Çorum, Elazığ, Elbistan, Ereğli, Eskişehir, Ilgın, Kastamonu, Kırşehir, Malatya, Turhal, Uşak and Yozgat sugar factories. The third has terrestrial climate and covers the Ağrı, Erciş, Erzincan, Erzurum, Kars and Muş sugar factories. Within the scope of this study, a total of 140 farms including 15 farms from the first region, 95 farms from the second region and 30 farms from the third region were evaluated. Due to the climate characteristics, maize and sunflower farming cannot be done in regions including the 3rd region. For this reason, maize and sunflower were evaluated on the basis of data from the remaining 110 farms. In the scope of the research; a total area of 1335 ha, including 177 ha (13%) in the first region, 945 ha (71%) in the second region and 213 ha (16%) in the third region were assessed.

The average land size of 140 farms in 25 regions where the survey was conducted in Turkey was 3.3 ha for sugar beet, 3.8 ha for wheat, 2.5 ha for sunflower and 2.2 ha for maize. These land sizes were not sufficient for efficient production. Therefore, as the input was increasing, the output was decreasing. Approximately 50 ha (4%) wheat planting area was irrigated by surface irrigation, 620 ha was irrigated by sprinkler irrigation method in 2nd region and the rest of the area and also wheat area in 3rd region was not irrigated (Turkseker, 2017-2018). In the calculation of the energy ratio, human, machinery, electricity, seed and fertilizer amounts and yield values of 4 crops were used (Mohammadi and Omid, 2010; Azizi and Heidari, 2013).

Table 1. Energy equivalents of inputs and outputs of the selected crops

Inputs	Unit	Energy equivalent coefficient (MJ/unit)			Sources
Human labor	h	1.96			Mohammadi and Omid, 2010
Machinery	h	62.70			Tipi *et al.* 2009
Nitrogen	kg	60.60			Singh, 2002
Phosphorous	kg	11.10			Singh, 2002
Potassium	kg	6.70			Singh, 2002
Chemicals	kg	120.00			Mandal *et al.* 2002
Fuel	l	56.31			Singh *et al.* 2002
Irrigation	m^3	1.02			Azizi and Heidari, 2013
Electricity	kWh	3.60			Ozkan *et al,* 2004
Crop	Unit	Energy equivalent coefficient (MJ/unit)			
		Seed	Output	By-product	
Sugar beet	kg	50.00	16.80	7.90	Chamsing *et al,* 2006
Wheat		5.00	14.70	12.50	
Sunflower		3.60	25.00	12.50	
Maize		14.70	14.70	12.50	

In this study, in order to estimate output energy values, sugar beet, wheat, **s**unflower and maize were taken into account (Table 1). Total energy input (ha) in a unit area constituted of the sum of input energy. Human labor, machinery, chemical fertilizers, chemicals, irrigation, electricity, Fuel and sugar beet seed were used as the inputs in calculation process (Mandal *et al.* 2002; Singh 2002; Singh et al. 2002; Ozkan *et al.* 2004 Tipi *et al.* 2009; Mohammadi and Omid, 2010; Azizi and Heidari, 2013). The output of the crop production consisted of main product and by products. Straw and bagasse were considered as by-products. The average ratio of grain and straw was about 1/1.5. In this study, it was assumed that utilization of straw as the by-product was equal to 20% of the grain weight with an energy equivalent to approximately 12.5 MJ/kg. For sugar beet, about 25% of it was assumed as bagasse with the energy equivalent to 7.9 MJ/kg (Chamsing *et al.* 2006) (Table 1).

The annual average temperature is approximately 15.8, 12.4, 8.5 °C and the total rainfall is 882, 403, 511 mm, of which about 72, 69, 64% falls from October to April in 1st, 2nd, 3rd group regions respectively (SugInst, 2017). The average land size in the regions where the survey is conducted is 2.1, 4.0, 2.9 ha respectively. Soil texture is clayey (32.1-47.3 % clay, 26.2-36.2 % silt, 17.5-41.7 % sand) and organic matter content is low (1.0-1.9%) in all regions (Sueri and Turhan, 2002).

Table 2. Energy inputs used per hectare (MJ ha^{-1})

	Inputs	Sugar beet	Rate (%)	Wheat	Rate (%)	Sunflower	Rate (%)	Maize	Rate (%)
1st region	Total Human Labor	93.69	0.15	25.68	0.10	42.53	0.14	61.15	0.16
	Total Machinery	2225.85	3.45	1210.11	4.48	2445.30	8.06	3316.83	8.85
	Chemical fertilizers	35579.00	55.22	14576.07	54.02	15394.02	50.75	20305.47	54.18
	Chemicals	264.00	0.41	144.00	0.53	228.00	0.75	276.00	0.74
	Irrigation	7324.01	11.37	3645.68	13.51	3930.67	12.96	4135.69	11.04
	Electricity[1]	3771.86	5.85	2819.52	10.45	3550.43	11.71	3580.60	9.55
	Fuel	14967.20	23.23	3513.74	13.02	4723.85	15.57	5213.74	13.91
	Seed	200.00	0.31	1050.00	3.89	16.20	0.05	588.00	1.57
2nd region	Total Human Labor	96.04	0.15	27.44	0.10	44.49	0.11	61.15	0.14
	Total Machinery	2671.02	4.15	1335.51	4.71	2746.26	6.93	3473.58	8.06
	Chemical fertilizers	29938.80	46.54	14161.80	49.96	23225.68	58.59	24892.80	57.75
	Chemicals	220.80	0.34	151.20	0.53	240.00	0.61	288.00	0.67
	Irrigation	8568.71	13.32	3730.24	13.16	4287.67	10.82	4441.69	10.30
	Electricity[1]	4516.56	7.02	3028.32	10.68	3622.32	9.14	3762.36	8.73
	Fuel	18120.56	28.17	4660.22	16.44	5456.44	13.76	5552.17	12.88
	Seed	200.00	0.31	1250.00	4.41	18.00	0.05	632.10	1.47
3rd region	Total Human Labor	117.21	0.17	22.34	0.12	43.71	0.15	59.19	0.17
	Total Machinery	2677.29	3.97	1548.69	8.39	2696.10	9.49	3555.09	10.19
	Chemical fertilizers	34869.80	51.73	10161.78	55.06	16503.16	58.09	16007.22	45.87
	Chemicals	220.80	0.33	0.00	0.00	0.00	0.00	336.00	0.96
	Irrigation	6528.61	9.68	0.00	0.00	1890.67	6.66	4320.83	12.38
	Electricity[1]	3414.24	5.06	0.00	0.00	1822.32	6.41	3660.12	10.49
	Fuel	19381.90	28.75	5473.33	29.66	5433.92	19.13	6357.40	18.22
	Seed	200.00	0.30	1250.00	6.77	18.00	0.06	602.70	1.73

[1] Electricity for pumping in irrigation of sugar beet

The input energy can also be classified as direct, indirect, renewable and non-renewable forms. While the indirect energy consists of pesticide and fertilizer, the direct energy includes human power, diesel fuel and electricity energy used in the production process. On the other hand, whereas non-renewable energy includes petrol, diesel, electricity, chemicals, fertilizers and machinery, renewable energy consists of human (Mandal *et al.* 2002). The calculations for energy input and output analysis is given in Table 2. Following formulas were used for calculation of the energy inputs, and output as well as the energy ratio for each crop (Mohammadi *et al.* 2008).

Energy use efficiency = output energy (MJ ha^{-1}) / input energy (MJ ha^{-1}) (1)

Energy productivity = crop output (kg ha^{-1}) / input energy (MJ ha^{-1}) (2)

Specific energy = input energy (MJ ha^{-1}) / crop output (kg ha^{-1}) (3)

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

3. RESULTS AND DISCUSSION

Regarding this study, the distributions of the inputs are given in Table 2. It can be seen that the first, second and third of the highest energy inputs in the selected productions are chemical fertilizer, diesel fuel and irrigation energy. On average, fertilizer had 45.87-58.59%, diesel fuel had 12.88-29.66%, and irrigation had 6.66-13.51 of physical energy inputs contributed to farm operations for all crops (Table 2).

The contribution of energy input to the farm operations for different crops is presented in Table 3. It shows that energy input varied according to the cultivated crop. In the farm operations, the energy input for sugar beet production was the highest (64425.61, 63587.80, 67767.48 MJ ha^{-1} in 1st, 2nd and 3rd regions respectively). The highest energy input in sugar beet was obtained in the third region. In this region, the high level of diesel energy as 19381.90 MJ ha^{-1} is decisive (Table 2). This is mainly due to the fact that the land was relatively small, amorphous. In addition, older generations tractors that had small-medium power (35-50 kW) were widely used. Maize is the second product with the highest energy input in all regions. The second region with the highest use of chemical fertilizers in particular has the highest energy input. The lowest energy input among the three regions is wheat. Especially non-irrigated wheat farming and chemical use in the third region, low chemical fertilizer usage and low fuel consumption in other regions caused low energy input.

Compared to human labor, mechanical energy had the highest input in the total physical energy inputs for different crops. Its contribution was about 95.95-98.58% of the total physical energy input for all crops (Table 2). Whereas the contribution of mechanical (1210.11, 1335.51, 1548.69 MJ ha^{-1}) and human labor energy input (25.68, 27.44, 22.34 MJ ha^{-1}) was the lowest for wheat production and the highest for maize production. For each crop, the variation in energy inputs in terms of farm operations depended on the cultural practices, type of machinery used and the required farm operations (Table 2).

According to the table, the highest direct energy inputs were 48.66, 40.38 % for sugar beet, wheat in second region respectively, 40.38 % for sunflower in first region and 41.26% for maize in third region. On the other hand the highest indirect energy inputs were 70.22 % for wheat in third region, 67.94 % for maize second region, 67.65 % for sunflower in third region and 59.40% of total energy input for sugar beet respectively in first region (Table 3).

Table 3. Total energy input according to energy type for different crops in each region

Region	Type of energy	Sugar beet	Ratio (%)	Wheat	Ratio (%)	Sunflower	Ratio (%)	Maize	Ratio (%)
1st region	Direct energy a	26156.76	40.60	10004.62	37.08	12247.48	40.38	12991.18	34.66
	Indirect energy b	38268.85	59.40	16980.18	62.92	18083.52	59.62	24486.30	65.34
	Total	64425.61	100.00	26984.80	100.00	30331.00	100.00	37477.48	100.00
	Renewable energy c	7617.70	11.82	4721.36	17.50	3989.40	13.15	4784.84	12.77
	Non-renewable energy d	56807.91	88.18	22263.44	82.50	26341.59	86.85	32692.64	87.23
	Total	64425.61	100.00	26984.80	100.00	30331.00	100.00	37477.48	100.00
2nd region	Direct energy	31301.87	48.66	11446.22	40.38	13410.92	33.83	13817.37	32.06
	Indirect energy	33030.62	51.34	16898.51	59.62	26229.94	66.17	29286.48	67.94
	Total	64332.49	100.00	28344.73	100.00	39640.86	100.00	43103.85	100.00
	Renewable energy	8864.75	13.78	5007.68	17.67	4350.16	10.97	5134.94	11.91
	Non-renewable energy	55467.74	86.22	23337.05	82.33	35290.70	89.03	37968.91	88.09
	Total	64332.49	100.00	28344.73	100.00	39640.86	100.00	43103.85	100.00
3rd region	Direct energy	29441.96	43.68	5495.68	29.78	9190.62	32.35	14397.54	41.26
	Indirect energy	37967.89	56.32	12960.47	70.22	19217.26	67.65	20501.01	58.74
	Total	67409.85	100.00	18456.15	100.00	28407.88	100.00	34898.55	100.00
	Renewable energy	6845.82	10.16	1272.34	6.89	1952.38	6.87	4982.72	14.28
	Non-renewable energy	60564.03	89.84	17183.80	93.11	26455.50	93.13	29915.83	85.72
	Total	67409.85	100.00	18456.15	100.00	28407.88	100.00	34898.55	100.00

a Includes human labor, fuel, electricity and irrigation
b Includes seed, chemical fertilizers, chemicals and machinery
c Includes human labor, seed and irrigation
d Includes diesel, chemicals, chemical fertilizers, machinery and electricity (Baran and Gökdoğan, 2016)

The energy from material inputs included chemical energy from fertilizer and pesticide, and biological energy from seeds. Non-renewable energy had the highest input to total energy inputs for different crops. It contributed about 82.33-93.13% of total energy input for all crops. Wheat had the lowest non-renewable energy input in 1st and 2nd regions and maize in 3rd region. Energy output included main product and by-product. Total energy input and output for sugar beet production was the highest (Table 3).

For different crops and regions, energy use efficiency (energy ratio) varied between 2.09 and 19.48 (Table 4). High energy ratios were corresponding to high efficiency in the use of energy and low mechanization level. Sugar beet showed the highest energy ratio in all regions, primarily in the first region (19.48). The main reason for the high yield of sugar beet in the first region is that sugar beet is started to cultivate about one month ago (late February - early March) depending on the climatic conditions. On the other hand, the high night temperatures in July and August months cause sugar content to be 20% lower than other regions. The second highest value was taken from the 2nd region for maize (4.63) and followed by sugar beet in other regions.

Table 4. Energy input-output and efficiency calculations for different crops

Calculations Unit Values		Unit	Sugar beet	Wheat	Sunflower	Maize
1st region	Yield	kg ha^{-1}	66830.00	4500.00	2506.00	8200.00
	Energy input	MJ ha^{-1}	64425.61	26984.80	30331.00	37477.48
	Energy output	MJ ha^{-1}	1254733.25	77400.00	68915.00	141040.00
	Energy use efficiency		19.48	2.87	2.27	3.76
	Energy productivity	kg MJ^{-1}	1.04	0.17	0.08	0.22
	Specific energy	MJ kg^{-1}	0.96	6.00	12.10	4.57
	Net energy	MJ ha^{-1}	1190307.64	50415.20	38584.00	103562.52
2nd region	Yield	kg ha^{-1}	58840.00	3912.40	3006.00	11600.00
	Energy input	MJ ha^{-1}	64332.49	28344.73	39640.86	43103.85
	Energy output	MJ ha^{-1}	1104721.00	67293.28	82665.00	199520.00
	Energy use efficiency		17.17	2.37	2.09	4.63
	Energy productivity	kg MJ^{-1}	0.91	0.14	0.08	0.27
	Specific energy	MJ kg^{-1}	1.09	7.24	13.19	3.72
	Net energy	MJ ha^{-1}	1040388.51	38948.55	43024.14	156416.15
3rd region	Yield	kg ha^{-1}	46000.00	3502.40	2806.00	9000.00
	Energy input	MJ ha^{-1}	67409.85	18456.15	28407.88	34898.55
	Energy output	MJ ha^{-1}	863650.00	60241.28	77165.00	154800.00
	Energy use efficiency		12.81	3.26	2.72	4.44
	Energy productivity	kg MJ^{-1}	0.68	0.19	0.10	0.26
	Specific energy	MJ kg^{-1}	1.47	5.27	10.12	3.88
	Net energy	MJ ha^{-1}	796240.15	41785.13	48757.13	119901.45

Efficiency of the energy use for sugar beet production was the highest with the values of 19.48, 17.17 and 12.81 in the regions respectively. On the other side the energy use efficiency was ranked as maize (3.76, 4.63, 4.44), wheat (2.87, 2.37, 3.26) and sunflower (2.27, 2.09 and 2.72) (Table 3). Some researchers reported that energy use efficiency was between 8.35 and 19.15 for sugar beet, 2.97 and 8.65 for wheat, 2.97 and 5.3 for maize and 2.95 for sunflower (Uzunoz *et al.* 2008; Asgharipour *et al.* 2012; Lorzadeh *et al.* 2012; Baran and Gökdoğan, 2016; Strnad and Misa, 2016; Shahgholi *et al.* 2018). This high energy ratio indicated to the lower inputs, especially to the low level of mechanization.

The specific energy that represents the energy used per unit of product, was the lowest in sugar beet production with the value of 0.96, 1.09, 1.47 MJ kg^{-1}, and the highest in sunflower 12.10, 13.19, 10.12 MJ kg^{-1} respectively. In terms of net energy, whereas the sugar beet production had the highest value in all regions particularly in 1st region with 1190307.64 MJ ha^{-1}, wheat production in the 2nd region had the lowest value with 38948.55 MJ ha^{-1} (Table 3). Examining some other countries, it is seen that the specific energy is 2.57, 2.66, 2.42, 3.99, 2.08, 2.60, 4.29 and 3.31 MJ kg^{-1} for wheat in the USA, Finland, Germany, Greece, Netherland, Poland, Portugal and Kenya, respectively; it is 4.11, 1.08 MJ kg^{-1} for maize in the USA and Indonesia, respectively; it is 0.22, 0.20 and 0.29 MJ kg^{-1} for sugar beet in Germany, Netherland and Poland, respectively and it is 5.06, 3.98 MJ kg^{-1} in Germany and Portugal for sunflower (Pimentel, 2009; Gołaszewski and de Visser, 2012). Abbas *et al.* (2018) described the specific energy as 6.68 MJ kg^{-1} for maize in Pakistan conditions. The high specific energy value in a product group refers to the high energy input, low output or both. In terms of Turkey, the specific energy value appears to be higher than the mentioned countries for these four products.

4. CONCLUSION

The average energy ratio of sugar beet, wheat, sunflower and corn production, which are the crops evaluated in the study, was calculated as 16.49, 2.84, 2.36, 4.28 respectively. The increasing crop productivity also increases the intensive agricultural practices that rely primarily on fossil fuel and some inputs such as fertilizers, pesticides and irrigation. Most of the developing countries generally utilize fertilizers and irrigation. In fact, it has been found that in the regions where the research was carried out, the tractor pulling power capacity owned by the farmer was matched to the farming technique applied by the farmer. On the other hand, the fact that 60% of the tractors in the second and third regions are aged 20 or over is considered as one of the factors that increase the fuel consumption. However, Turkey now has to search for ways in order to make agriculture more efficient with large machines in large-scale agricultural areas. There is a positive linear relationship between energy output/input ratio and crop production; that is, methods of farming with high energy output/input ratio must be used to accomplish greater production. In addition, despite the state support, most of the farmers were still applying fertilizer with traditional understanding and methods instead of soil sampling, and generally two or three times more than recommended amount.

Looking at the distribution of inputs used in the production of crops according to the direct, indirect, renewable and non-renewable energy groups, it can be seen that the use of indirect energy was higher than the direct energy, and non-renewable energy was higher than renewable energy for all crops. Efficiency of the energy usage is one of the principal requirements of sustainable agriculture.

In conclusion, developing countries such as Turkey must use more effective methods and policies that may reduce the negative effects of high energy inputs. Besides, these countries should find a solution to make larger-scale agriculture by combining fragmented small-scale land as soon as possible. In addition, they must do more research on precision agriculture by using variable rate applications (VRA). They also have to develop more efficient, economical and environment friendly agricultural production systems that can be increase efficiency of energy usage. Apart from these, applications that can be made to reduce energy use in agriculture and increase energy efficiency can be summarized as follows:

1. Conservation, reduced or no tillage system can be applied instead of the traditional tillage method.
2. The use of chemicals can be reduced by applying different farming systems, such as sequential or mixed cultivation techniques.
3. In addition to determining the effective fertilizer need with soil analysis, expanding the use of liquid and solid organic fertilizers and microbial fertilizers, fertilizer application with irrigation can be beneficial in terms of reducing energy input.
4. Irrigation of agricultural crops has an important consumption of electricity or fuel after fertilization. Energy saving in agricultural irrigation is possible with proper selection of irrigation equipment and arrangement with more efficient pump usage in irrigation as well as with a good irrigation program.
5. Other way farmers can protect themselves against high energy consumption and cost is through the adoption of on farm renewable energy systems such as wind or solar technology and use of biofuels instead of fossil fuels in various applications.

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