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Evaluation of the Energy Analyses of Wheat Production at the Geographical Regions of Turkey

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ABSTRACT

In this study, the energy analyses of wheat production were compared for various geographic regions as Central Anatolia, Black Sea, Mediterranean, Eastern Anatolia and the Marmara. For this purpose, the data obtained from different studies conducted in these geographical regions were used. Five key indicators to assess the energy analyses in wheat production in the geographical regions of Turkey (energy profitability, specific energy, energy efficiency, energy use and net energy) were considered. As a result, the lowest specific energy was obtained in the Mediterranean/Adana region with 2.22 MJ kg^{-1}, while the highest specific energy was obtained in the East Anatolia with 10.51 MJ kg^{-1}. The lowest and highest energy use efficiency was obtained with 2.36 and 7.88 in the Black Sea/Samsun and East Anatolia/Erzurum region, respectively. The highest energy use rate is fertilizer energy in total input energy of the wheat production for geographical regions of Turkey.

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Introduction

Wheat is one of the most important grains for human nutrition and is the main food source. At least, for 11 000 years, wheat has been cultivating in the world. Wheat production was made in 65 million hectares area as 22 million tonnes for Turkey in 2019 according to the Turkish Statistical Institute data (TUIK, 2020). Turkey has a total land area of 78 million hectares. Turkey is one of the leading actors of major cereal production around the world. The cereal production areas occupy seventy five percent of the total utilized agricultural area of Turkey. The most wheat production regions are Central Anatolia (36%), Marmara (15%) and South eastern Anatolia (14%) regions in terms of the regional regions in Turkey (ZMO, 2017).

Between agriculture and energy, there is a strong connection. With regard to bioenergy, agriculture is an energy user and provider (Singh et al., 1997). With a high level of living situations with increasing populations in limited agricultural arable land, the energy use in agriculture has generally increased. To minimize labor-intensive applications and maximize productivity in agricultural production, all the countries in the world have increased their energy input (Esengun et al., 2007).

Energy use efficiency is one of the basic requirements for sustainable agricultural production for wheat. Energy use in agricultural production is increasing as a result of the intensive use of pesticides, chemical fertilizers, agricultural machinery and other natural resources to increase food production and respond to demand. Therefore, in agricultural practices; fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. input uses have increased steadily (Yadav and Khandelwal, 2013).

Energy use efficiency promotes sustainable agriculture, prevents the destruction of natural resources, and minimizes negative environmental effects in agriculture (Erdal et al., 2007). For this reason, in several agricultural production regions, many researchers are conducting researches on energy management issues. To determine the efficiency and the environmental impact of energy, the analyses of input-output energy in agricultural systems has been widely used. Increasing the use of energy causes significant health and environmental problems in Turkey. Therefore, for sustainable agriculture, the effective use of energy inputs has begun to gain importance in Turkey.

To evaluate the energy analysis, the important indicators were considered as, energy productivity, energy profitability, energy use efficiency, specific energy, net energy. In order to determine the energy use efficiency for wheat production, several scientific publications and articles (Canakci et al., 2005; Çarman et al., 2009; Tipi et al., 2009; Cicek et al., 2011; Gözübüyük et al., 2012; Karaağaç et al., 2012; Gökdoğan and Sevim, 2016; Yıldız, 2016) have been investigated for the seven different regions in Turkey.

For this purpose, the wheat energy analysis of data was obtained from studies in the different geographical regions of Turkey on wheat productions as the Central Anatolia (Konya and Aksaray), Black Sea (Tokat and Samsun), Marmara (Balikesir, Edirne, Tekirdag), the Mediterranean (Antalya and Çukurova) and East Anatolia (Erzurum). The objective of this study was to compare the energy analysis of wheat production in the different geographical regions of Turkey. In order to determine the energy use efficiency, for the different regions the energy analysis data were obtained from wheat productions in Turkey. These geographical regions map is shown in Figure 1.

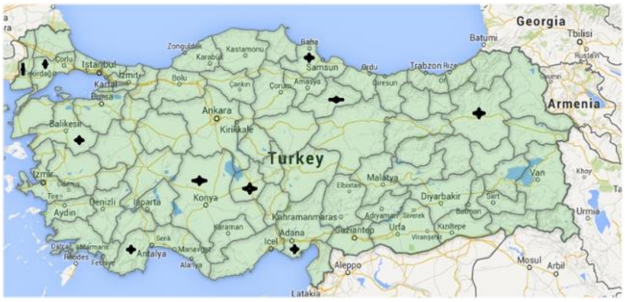

Figure 1. Turkey map showing various geographic regions for energy analysis studies of wheat production in Central Anatolia, Black Sea, Mediterranean, Eastern Anatolia, and the Marmara regions (Anonymous, 2020).

Materials and Methods

In order to determine the energy use efficiency of wheat productions, for the different regions, the energy analysis data were obtained from below studies in Turkey. These are;

East Anatolia Region	
Erzurum	Gözübüyük et al. (2012)
Marmara Region	
Balıkesir-Edirne-Tekirdag	Tipi et al. (2009)
Mediterranean Region	
Antalya	Canakci et al. (2005)
Adana / Cukurova	Karaağaç et al. (2012)
Black Sea Region	
Tokat	Cicek et al. (2011)
Samsun	Yıldız (2016)
Middle Anatolia Region	
Konya	Çarman et al. (2009)
Aksaray	Gökdoğan and Sevim (2016).

The climate data as the relative humidity, long-term average temperature, rainfall, the altitude, longitude, and latitude of the cities studied in geographical regions are given in Table 1. According to the geographical regions of Turkey, the energy analysis results were obtained from the studies on the energy equivalents of the production inputs and outputs used in wheat production. Energy equivalents (MJ unit^{-1}) for different inputs and outputs in wheat production according to the geographical region of Turkey were given in Table 2.

EP (energy productivity), NE (net energy), SE (specific energy), EUE (energy use efficiency), and EP (energy profitability) parameters were used to compare energy use efficiency in wheat production for the geographical regions of Turkey. For this purpose, energy use efficiency parameter values determined by the equations given below were used in the studies evaluated as examples (Mandal et al., 2002; Mohammadi et al., 2008; Mohammadi et al., 2010).

$$EP = Y/EI \quad (1)$$
$$NE = EI - EO \quad (2)$$
$$SE = EI/Y \quad (3)$$
$$EUE = EO/EI \quad (4)$$
$$EP = NE/EI \quad (5)$$

Where;
EP Is energy productivity (kg MJ^{-1})
Y Is yield (kg ha^{-1})
EI Is energy input (MJ ha^{-1})
NE Is net energy (MJ ha^{-1})
EO Is energy output (MJ ha^{-1})
SE Is specific energy (MJ kg^{-1})
EUE Is energy use efficiency
EP Is energy profitability.

Results and Discussion

The following results of the energy analyses of wheat production in different geographical regions of Turkey were obtained. In these studies; no animal power or electricity source was used in wheat productions. Electricity was used in Aksaray study. Agricultural tool and machines used in all agricultural applications for wheat production were powered by a tractor. For the Mediterranean/Antalya province, the total energy input used for cultivating the wheat crop in various farm operations was calculated to be 18 680.8 MJ ha^{-1}.

For the Mediterranean/Antalya province; the energy use efficiency value was found as 2.80 MJ kg^{-1} in flat planting to take account of energy output/input rate (Table 3 and Table 4). Seedbed preparation in wheat production has maximum energy (65.1%). This is followed by harvest (22.9%), and the transport (8.7%) used on the other agricultural applications. The chemical fertilizer application constitutes the highest energy source in wheat production with a rate of 54.1% (Canakci et al., 2005).

For the Çukurova region/Adana province; the specific energy value was calculated 2.22 MJ kg^{-1} in flat planting to take account of energy output/input rate (Table 4). This rate was obtained 6.63 in flat planting. The highest energy usage proportion is fertilizer energy in wheat production in total input energy (Karaağaç et al., 2012).

Table 1. The latitude, longitude, altitude and climate data of the cities studied in geographical regions of Turkey (*)

Province/ Geographical Region	Climate Data						
	Latitude	Longitude	Altitude (m)	Temperature (°C, min.)	Temperature (°C, max.)	Evaporation rate (%)	Rainfall mm/year
Erzurum/ East Anatolia	39° 54' 0"	41° 16' 12"	1893	-0.4	11.9	62	692
Balıkesir/ Marmara	39° 38' 54"	27° 52' 57"	101	9.0	20.4	53	696
Edirne/ Marmara	41° 40' 54"	26° 33' 44"	48	8.3	19.6	54	597
Marmara/ Tekirdag	40° 59' 0"	27° 31' 0"	3	10.3	17.9	52	712
Antalya/ Mediterranean	36° 53' 3"	30° 42' 20"	43	13.7	24.1	53	1083
Çukurova/ Mediterranean	37° 0' 0"	35° 19' 17"	23	13.8	25.3	42	791
Tokat/ Black Sea	40° 19' 0"	36° 33' 0"	623	7.0	18.7	52	554
Samsun/ Black Sea	41° 17' 34"	36° 19' 53"	44	11.0	18.2	50	551
Konya/ Middle Anatolia	37° 52' 0"	32° 29' 0"	1026	5.3	18.0	56	548
Aksaray/ Middle Anatolia/	38° 22' 7"	34° 2' 13"	900	6.1	18.6	56	327

*(Anonymous, 2017)

Table 2. Energy equivalents (MJ unit^{-1}) for different inputs and outputs in wheat production according to geographical region of Turkey (*)

Particulars	Geographical Regions							
	Mediterranean		Middle Anatolia		Marmara	Black Sea		East Anatolia
	Adana	Antalya	Konya	Aksaray	Marmara	Tokat	Samsun	Erzurum
Input								
Human Labor (h)	2.3	1.96	2.3	1.96	1.96	1.96	1.95	2.3
Women labor (h)	–	1.57	–	–	–	–	–	–
Tractor	158.3	93.61	158.3	–	–	–	–	158.5
Harvesting (combine)	-	87.63	–	87.63	87.63	–	–	–
Machinery	121.3	62.7	121.3	64.8	62.7	62.7	62.7	121.3
Diesel	47.8	47.8	47.8	–	–	–	–	35.69
Oil	42.5	–	42.5	–	–	–	–	6.51
Electricity	–	–	–	3.6	–	–	3.6	–
Fertilizers (kg)	–	–	–	–	–	–	–	–
Azote	60.6	60.6	60.6	60.6	64.4	66.14	75.46	66.14
Phosphorus (P_2O_5)	11.1	11.1	11.1	11.1	11.1	12.44	13.07	12.44
Potassium (K_2O)	-	6.7	–	–	–	–	11.15	11.15
DAP	-	–	–	–	–	–	–	–
Sulphur	-	–	–	1.12	–	–	–	-
Urea	-	–	–	–	–	–	–	-
Chemicals (kg)	–	120	–	101.2	101.2	–	–	–
Herbicide	238	–	238	–	–	238	–	101.2
2.4 D	–	–	–	–	–	–	84.91	–
Topic	–	–	–	–	–	–	271.38	–
Pesticide	-	–	–	–	–	–	280.44	–
Insecticide	-	–	–	–	–	–	–	-
Fungicide	-	–	–	–	–	–	181.9	–
Farmyard manure	–	0.3	–	–	–	–	–	–
Nylon	–	60	–	–	–	–	–	–
Seed (kg)	15	15.7	15	–	15.7	15.7	20.1	16.7
Irrigation (m^3)	-	–	–	1.02	–	0.63	1.02	-
Output								
Grain	14.7	14.7	14.7	14.7	14.7	14.7	14.48	16.7
Wheat Stalk	12.5	–	12.5	–	–	12.5	2.25	17.17

(*): Canakci et al. (2005); Çarman et al. (2009); Tipi et al. (2009); Cicek et al. (2011); Gözübüyük et al. (2012); Karaağaç et al. (2012); Yıldız (2016); Gökdoğan and Sevim (2016).

For East Anatolia region/Erzurum province, according to the results, the chemical fertilizer applied considering the results of soil analysis has arguably been the highest rate of energy input in terms of energy distribution ratios of all systems in both farming conditions followed by seed, fuel-oil, machinery manufacturing, and human labor energy rates. The energy use efficiency value was found as 7.88 MJ kg^{-1} (Table 3, Table 4). (Gözübüyük et al., 2012).

For the Marmara region, the mean energy output-input ratio (energy use efficiency) was found as 3.09 (Table 4). The highest share in the total energy consumption was obtained from the energy input of diesel (45.15%), fertilizers (34.21%), especially nitrogen fertilizer (31.77%), respectively. The energy output-input ratio increased as the farm size increased. There is a lower renewable form of energy input (15.4%) than the non-renewable form of energy input (84.6%). Because the energy input use is mainly obtained from fossil fuels in wheat production (Tipi et al., 2009).

Table 3. Energy inputs and outputs (MJ ha^{-1}) in wheat production for different inputs and outputs (*)

Operations in production	Mediterranean		Middle Anatolia	
	Çukurova	Antalya	Konya	Aksaray
Human Labor	9.48	18.9	7.98	51.94
Tillage operation	1.29			
Sowing and other	5.11			
Harvesting	3.08			
Machine	436.98	474.8	402.3	358.61
Tractor	72.15		182	
Land preparation	22.7		220.3	292.89
Sowing and other	90.13			
Harvesting	252			65.72
Diesel and Oil	2,428.46	3,241.7	2,928.22	3,383.1
Land preparation	1,043.96			
Sowing and other	638.81			
Harvesting	745.69			
Fertilizer	12,437.46	10,115.4	5,604.9	11,345.05
Azote	765.9		4,521.6	1,009.65
Phosphorus	11,671.56		1,083.3	10,27.45
Sulphur				7.95
Chemical	79.73	120	360	123.46
Herbicide	79.73			
Seed	3,000	4,710	5,500	3,898
Irrigation				3,605.48
Electricity				2,871.93
Transportation				238.72
Land rent				
Total input energy	18,392.1	18,680.8	14,803.4	25,876.29
Output				
Grain	77,571.9	52,306.24	32,540.9	76,990.96
Wheat Stalk	44,375	-	-	-
Total output energy	121,946.9	52,306.24	32,540.9	76,990.96

Operations in production	Marmara	Black Sea		East Anatolia
	Marmara	Tokat	Samsun	Erzurum
Human Labor	35.89	66.05	134.88	24.81
Tillage operation	20.33	38.42	10.9	12.38
Sowing and other	12.52	19.8	14.43	7.5
Harvesting	3.04	7.84	109.55	4.93
Machine	879.21	627	3,523.11	721.23
Tractor				315.13
Land preparation	503.43	476.52	587.5	99.98
Sowing and other	203.15	50.16	280.9	57.87
Harvesting	172.63	100.32	2,654.72	248.24
Diesel and Oil	9,324.94	2,985.56	15,942.49	2,236.18
Land preparation				
Sowing and other				
Harvesting				
Fertilizer	7,065.23	4,123.48	8,412.51	9,491
Azote	6,561.07	3,439.28	7,779.93	
Phosphorus	504.16	684.2	632.59	
Sulphur				
Chemical	148.65	476	330.56	
Herbicide				
Seed	3,148.16	2983	3,613.58	3,006
Irrigation		1,944.81	3,780	
Electricity				
Transportation	52.38			
Land rent				
Total input energy	20,653.54	13,205.9	35,737.13	15,479
Output				
Grain	63,886.2	50,127	57,742.19	24,585.3
Wheat Stalk	-	-	26,685.14	-
Total output energy	63,886.2	50,127	84,427.33	24,585.3

(*): Canakci et al. (2005); Çarman et al. (2009); Tipi et al. (2009); Cicek et al. (2011); Gözübüyük et al. (2012); Karaağaç et al. (2012); Yıldız (2016); Gökdoğan and Sevim (2016).

For the Central Anatolia region/Konya province; the highest proportion in energy usage is fertilizer energy, followed by seed, fuel-oil, and machine energies, in total input energy of the wheat production, respectively (Table 3). The highest rate of energy output/input in wheat production in Konuklar farm obtained as 3.231, 3.647 and 4.094 for direct seeding with herbicides application in 2007, 2008, and 2009 years, respectively. The highest rate of energy output/input in wheat production in Polatlı farm obtained as 1.302 for direct seeding with herbicides application in 2007, as 2.609 for direct seeding application in 2008, and as 3.784 for direct seeding with herbicides application in 2009 (Çarman et al., 2009).

For Central Anatolia/Aksaray province, the chemical fertilizers are an important part of the inputs in wheat production (Table 3). Therefore, farm manure can be used in wheat production instead of chemical fertilizer. The ratio of renewable energy is lower than non-renewable energy the ratio, and the ratio of direct energy is lower than the indirect energy the ratio. Among the inputs, the chemical fertilizer level could be decreased (Gökdoğan and Sevim, 2016).

For the Black Sea region/Samsun province, the energy productivity, net energy, specific energy, and energy use efficiency for wheat production were found as 0.16 kg MJ^{-1}, 48 690.20 MJ ha^{-1}, 6.13 MJ kg^{-1}, and 2.36, respectively (Table 4). Integrated pest control techniques should be applied to reduce pesticide use and increase efficiency in energy use. For sustainable agriculture, fertilizer applications should be made efficient in order to reduce production costs and to reduce negative effects on human health and the environment (Yıldız, 2016).

For the Middle Black Sea/Tokat province, the mean energy output-input ratio (energy use efficiency) was found as 3.80 (Table 4). The amount of energies consumed was 14 134. 93 MJ ha^{-1} and 13 205.90 MJ ha^{-1} in rainfed and irrigated treatments in wheat production, respectively. The total energy input used in non-renewable and renewable energy were found 75% and 25% in rainfed wheat production, respectively. Intensive input uses raise some problems like environmental pollution and global warming in irrigated wheat and rainfed wheat productions (Cicek et al., 2011).

Table 4. Energy indicators in wheat production for geographical region of Turkey (*)

	Mediterranean		Middle Anatolia		Marmara	Black Sea		East Anatolia
Energy Indicators	Çukurova	Antalya	Konya	Aksaray	Marmara	Tokat	Samsun	Erzurum
Energy use efficiency	6.63	2.80	2.20	2.98	3.09	3.80	2.36	7.88
Specific energy (MJ kg^{-1})	2.22	5.25	6.69	4.94	4.75	3.87	6.13	10.51
Energy productivity (kg MJ^{-1})	0.45	0.19	0.15	0.20	0.21	0.26	0.16	0.10
Net energy (MJ ha^{-1})	103,554.8	33,625.4	17,736.6	51,114.7	43,232.7	36,921.1	48,690.2	106,467.9
Energy profitability	0.85	0.64	0.55	0.66	0.68	0.74	0.57	0.87

(*): Canakci et al. (2005); Çarman et al. (2009); Tipi et al. (2009); Cicek et al. (2011); Gözübüyük et al. (2012); Karaağaç et al. (2012);

Conclusion

According to the results, the energy analysis data for the different geographical regions of Turkey, the lowest and highest specific energy were obtained in the East Anatolia region, and Black Sea regions, respectively. The lowest energy use efficiency was obtained in the Black Sea region, whereas, the highest input/output ratio was obtained in the East Anatolia region. The lowest and highest energy profitability for wheat production were obtained in the Black Sea and the East Anatolia regions, respectively. The lowest and highest net energy for wheat production was obtained in East Anatolia and the Black Sea regions. In general, the highest energy usage proportion is fertilizer energy in wheat production in total input energy for the different geographical regions of Turkey. It is quite remarkable that the chemical fertilizer energy input is highest when it is evaluated in terms of sustainable agricultural production. Therefore, the chemical fertilizer level could be decreased among the inputs. It is seen that the inputs and outputs used in wheat production are different in the examined studies. Accordingly, it is one of the reasons for regional differences in energy use parameters. In conclusion, due to a lot of factors such as the different agricultural practices and technologies in different regions, climate, geographical factors, crop yield, economic effects in different regions in Turkey, the energy indicators and energy usage efficiency of the regions in terms of sustainable wheat production may be changed according to the geographical regions. In particular, the agricultural production is based on wheat and very intensive in Central Anatolia. Therefore, the production systems that will ensure sustainability in terms of energy use, soil and water resources, environment, economy, and efficiency should be determined. With this study, the energy use efficiency in wheat production was compared regionally and attention was drawn to the need for appropriate agricultural practices in order to increase the energy use efficiency for sustainable agriculture. Therefore, the required improvements in agricultural practices should be made to increase energy use efficiency and energy profitability.

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