ANADOLU, J. of AARI
ISSN: 1300-0225 (Print)
E-ISSN: 2667-6087 (Online)
2022, 32 (2): 277-286
DOI: 10.18615/anadolu.1225576

Comparative Analysis of Energy Use Efficiency and Greenhouse Gas Emission of Wheat Farming in Edirne Province of Türkiye

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Received (Geliş tarihi):02.06.2022 Accepted (Kabul tarihi): 24.10.2022

ABSTRACT: *This study aimed to determine the energy use efficiency and greenhouse gas emission of wheat production in enterprises that had soil analysis or not. A survey was conducted with 60 producers who had soil analysis in three laboratories in Edirne province, which accepted the most sampling for soil analysis and gave fertilizer recommendations in 2015 and 40 producers who did not have soil analysis in the same region. Thus, a total of 100 producers were interviewed. Energy use efficiency, energy productivity, specific energy and net energy were 3.54, 0.20 kg MJ^{-1}, 5.09 MJ kg^{-1} and 60191.34 MJ in the enterprises that had soil analysis, respectively. On the other hand, these values were 3.19, 0.17 kg MJ^{-1}, 5.74 MJ kg^{-1}, and 54508.49 MJ in the enterprises that did not have soil analysis. Greenhouse gas (GHG) ratios per kg were found as 0.66 and 0.72 for the wheat production in the enterprises that had and did not have soil analysis, respectively. In the enterprises that had soil analysis, the shares of the chemical fertilizers in energy use and total GHG emissions were lower than the other producer group. As a result of the analysis, it was determined that wheat production in the enterprises that had soil analysis was more efficient in terms of energy use and greenhouse gas emissions compared to enterprises that did not have analysis and these results revealed the importance of having soil analysis and applying fertilizer amounts according to soil analysis results.*

Keywords: *Wheat, energy use, greenhouse gas emission.*

Edirne İlinde Buğday Üretiminde Enerji Kullanım Etkinliği ve Sera Gazı Emisyonunun Karşılaştırmalı Analizi

ÖZ: *Bu çalışmada Edirne ilinde toprak analizi yaptıran ve yaptırmayan işletmelerde buğday üretiminin enerji kullanım etkinliği ve sera gazı emisyonunun belirlenmesi amaçlanmıştır. Edirne ilinde toprak analizi için en fazla numune alımı kabul eden ve gübre tavsiyesi veren üç laboratuvarda 2015 yılında toprak analizi yaptıran 60 üretici ve aynı bölgede toprak analizi yaptırmayan 40 üretici ile anket çalışması yapılmış olup, toplamda 100 üretici ile görüşülmüştür. Toprak analizi yaptıran işletmelerde enerji kullanım etkinliği, enerji verimliliği, spesifik enerji ve net enerji sırasıyla 3,54, 0,20 kg MJ^{-1}, 5,09 MJ kg^{-1} ve 60191.34 MJ, toprak analizi yaptırmayan işletmelerde ise sırasıyla 3,19, 0,17 kg MJ^{-1}, 5,74 MJ kg^{-1} ve 54508.49 MJ olarak bulunmuştur. Toprak analizi yaptıran ve yaptırmayan işletmelerde buğday üretimi için kg başına sera gazı oranları sırasıyla 0,66 ve 0,72 olarak bulunmuştur. Toprak analizi yaptıran işletmelerde kimyasal gübrelerin enerji kullanımı ve toplam sera gazı emisyonlarındaki payları diğer üretici grubuna göre daha düşüktür. Yapılan analizler sonucunda, toprak analizi yaptıran işletmelerde buğday üretiminin enerji kullanımı ve sera gazı emisyonları bakımından analiz yaptırmayan işletmelere göre daha verimli olduğu belirlenmiş olup, bu sonuçlar toprak analizi yaptırmanın ve gübre miktarını toprak analiz sonuçlarına göre uygulamanın önemini ortaya çıkarmaktadır.*

Anahtar kelimeler: *Buğday, enerji kullanımı, sera gazı emisyonu.*

INTRODUCTION

Grains, the essential nutritional sources of human beings, are among the most produced crops in the world, and wheat is one of the most cultivated and consumed products among cereals. The wide adaptability, nutritional value, ease of processing and market demand for wheat crops are the main reasons producers focus on wheat farming. In addition, wheat is preferred by producers with its advantage in storage. Wheat, the main food of 50 countries in the world, is the raw material of many foods that reach the table, so the consumer's demand is continuous.

Wheat has the ability to grow in all kinds of soils. The highest yield in wheat cultivation is obtained from clayey and humus-rich soils. In order for wheat to be grown, the soil must first be cultivated. Wheat needs plenty of moist air and low temperatures in its early stages. Soil temperature is important for wheat cultivation and this temperature should be around ten degrees. In this way, the wheat plant will take root more quickly in the soil and will not be affected by the harsh cold of winter. This desired temperature is generally achieved between October and November for each region. Soil depth for wheat planting should be in the range of almost four to six centimeters for seed. A modern sowing machine, seeder, is used in wheat sowing. Wheat cultivation can be done once a year for the same soil. Wheat is the most produced agricultural product in the world and in Türkiye.

In Türkiye, the importance of wheat farming is gradually increasing due to cereals' consumption habits, especially wheat and wheat products. Wheat is the raw material of bread, bulgur, pasta, starch, biscuits, wafers and confectionery, which are consumed most as food. Likewise, the stems of the wheat plant are also used significantly in the paper-cardboard industry and animal nutrition (Oyewole, 2016).

The total wheat cultivation areas in the world were 224.7 million hectares in the 2020/21 production period, and the total production was 774.3 million tons. Türkiye meets 3% of the world wheat cultivation area with 6.8 million hectares, and 2.65% of the world wheat production with 20.5 million tons. This area also constitutes 44% of Türkiye's total cultivated grain area (Anonymous, 2021). The share of wheat cultivation area in Edirne (135284 ha) in Türkiye is 2%, and the share of production amount (478487 tons) in Türkiye's production is 2.33% (Anonymous, 2022a).

Although the agricultural sector in Türkiye does not have much energy consumption, there is significant energy consumption in rural areas due to the fact that it creates many processes such as tillage, planting, weed control, irrigation, fertilization, harvesting, transportation and drying (Yaldız *et al.*, 1990). Limited arable land and ever-increasing food consumption for increasing population and high living standards have led to the intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources in agricultural production. Intensive energy use causes problems that threaten human health and natural habitats. The efficient use of energy in agricultural production will minimize environmental problems, prevent damage to natural resources and promote sustainable agriculture as an economical production system (Erdal *et al.*, 2007). When the effective use of energy resources, one of the basic requirements for sustainable agricultural production, is ensured, fossil resources are protected and it is possible to reduce air pollution. In order to increase energy efficiency, steps should be taken to increase production yield or protect energy input without affecting the yield (Singh *et al.*, 2004).

More energy use creates important environmental problems affecting human health such as greenhouse gas emissions. Therefore, more economical use of inputs becomes important for sustainable agricultural production. Greenhouse gas emissions in agriculture occur due to machine use, fuel consumption, use of chemical pesticides, chemical fertilizers, livestock and electricity consumption (Karaağaç *et al.*, 2019).

According to greenhouse gas inventory results, total GHG (greenhouse gas) emissions were estimated to be 523.9 Mt of $CO_{2\text{-eq}}$ in 2020 in Türkiye. This represented an increase of 15.8 Mt, or 3.1% in emissions compared to 2019, and a 138.4% increase compared to 1990. In 2020, the energy sector had the largest portion with a 70.2% share of total emissions. The energy sector was followed by the sectors of agriculture with 14%, industrial processes and product use (IPPU) with 12.7% and waste with

3.1%. Agriculture sector emissions were 73.16 Mt of $CO_{2\text{-eq}}$ in 2020 in Türkiye. This represented an increase of 7.5% in emissions compared to 2019, and a 58.8% increase compared to 1990. Total GHG emissions per person were calculated as 4 tons of $CO_{2\text{-eq}}$ in 1990, 6.2 tons of $CO_{2\text{-eq}}$ in 2019 and 6.3 tons of $CO_{2\text{-eq}}$ in 2020 in Türkiye (Anonymous, 2022b).

Insufficient use of agricultural inputs in Türkiye causes waste of resources, deterioration of natural resources, and a decrease in the quality and yield of products. This problem is especially evident in the use of fertilizers. Good fertilization is done by determining the plant's type and amount of fertilizer and applying it to the soil at the right time, according to the appropriate technique. Various soil samples are taken from a certain area and the type and amount of fertilizer required for the soil are determined in specialized laboratories. By means of soil analysis, the nutrients needed by the soil can be determined accurately. Thus, the untimely, incomplete or excessive use of fertilizers is avoided (Güldal, 2016).

When the literature was examined, it was seen that there were many studies that determined the efficiency of energy use in wheat production in Türkiye and the world, some of them were carried out by Singh *et al.,* 2004; Oren and Oztürk 2006; Shahin *et al.,* 2008; Tipi *et al.,* 2009; Khan *et al.,* 2010; Safa *et al.,* 2010; Ghorbani *et al.,* 2011; Ramah and Baali, 2013; Kardoni *et al.,* 2014; Marin *et al.,* 2015; Ziaei *et al.,* 2015; Gökdoğan and Sevim 2016; Gültekin *et al.,* 2016; Yıldız, 2016; Abbas *et al.,* 2017; Unakıtan and Aydın, 2018; Altuntaş *et al.,* 2019 and Nassir *et al.,* 2021. Besides, some studies on the determination of GHG emissions in the production of some crops including wheat were conducted by Rajaniemi *et al.,* 2011; Soltani *et al.,* 2013; Syp *et al.,* 2015 and Eren *et al.,* 2019.

This study aimed to find the inputs used in wheat production and the energy equivalents of these inputs in agricultural enterprises that had soil analysis or not in Edirne province of Türkiye. Comparative energy output/input analysis was made and the efficiency degrees of the inputs were also determined. In addition, GHG emissions in wheat production were determined, and the effects of soil analysis on energy use and greenhouse gas emissions were revealed.

MATERIAL and METHOD

The primary data of the research consisted of the data obtained from the survey studies conducted with the producers who had soil analysis in 2015 in the laboratories that accepted the most sampling for soil analysis and gave fertilizer advice, and with the producers who did not have soil analysis in the same region. Secondary data in the research was obtained from the reports of the Turkish Statistical Institute, TR Ministry of Agriculture and Forestry, domestic and foreign universities, extension services and previous studies.

Three of the laboratories with the highest number of soil analyses were included in the sample. A total of 60 producers, 20 of whom applied to each laboratory in 2015 and had soil analysis, 40 producers with similar characteristics (land size, product pattern, *etc.*) that did not have soil analysis in the regions where the same laboratories were located, consequently, a total of 100 producers were interviewed.

Descriptive statistics such as mean, standard deviation, percentage and cross tables were used in the data analysis. In the study, all data were first subjected to normality test. Since the number of samples was over 30, the Kolmogorow-Smirnov test was applied in the normality test and it was determined that the data were not normally distributed. Therefore, Mann Whitney U test was performed on the data. During the analysis of the data, Excel and IBM®SPSS 26 package program were used (Anonymous, 2022c).

In order to determine the energy output/input analysis, the inputs used in wheat production and the output obtained from the production were found. Input amounts were calculated per hectare and these data were multiplied by the energy equivalent coefficients. The units shown in Table 1 were used to find the equivalents of the inputs, and the energy equivalent coefficients were obtained from previous studies. The energy equivalents of the inputs were expressed in megajoules (MJ), and the total input equivalent was calculated by summing the energy equivalents of all inputs.

Table 1. Energy equivalents of inputs and outputs in wheat production.
Çizelge 1. Buğday üretiminde girdi ve çıktıların enerji eşdeğerleri.

Inputs Girdiler	Energy equivalents (MJ unit^{-1}) Enerji eşdeğerleri (MJ birim^{-1})	References Kaynaklar
Labor (h) /İşgücü	1.96	Singh, 2002
Machinery (h) /Çekigücü	64.80	Singh, 2002
Combine (h) /Biçerdöver	87.63	Hetz, 1992
Fuel (l) /Yakıt	56.31	Singh, 2002
Fertilizer (kg) /Gübre		
Nitrogen /Azot	60.60	Singh, 2002
Phosphorus /Fosfor	11.15	Singh, 2002
Pesticides (kg) /Tarım ilaçları		
Herbicides /Ot ilaçları	238.00	Rafiee *et al.*, 2010
Fungicides /Mantar ilaçları	216.00	Rafiee *et al.*, 2010
Seed (kg) /Tohum	20.10	Ghorbani *et al.*, 2011
Outputs Çıktılar		
Wheat (kg) /Buğday	14.48	Ghorbani *et al.*, 2011
Wheat straw (kg)/ Buğday samanı	9.20	Ghorbani *et al.*, 2011

The energy use efficiency and energy efficiency coefficients in wheat production were calculated and the following formulas were used for these calculations (Mandal *et al.*, 2002).

$$Energy\ use\ efficiency = \frac{Energy\ output\ (MJ\ ha^{-1})}{Energy\ input\ (MJ\ ha^{-1})}$$

$$Specific\ energy = \frac{Energy\ input (MJ\ ha^{-1})}{Yield\ (kg\ ha^{-1})}$$

$$Energy\ productivity = \frac{Yield\ \ (kg\ ha^{-1})}{Enerji\ input\ (MJ\ ha^{-1})}$$

$$Net\ energy = Energy\ output\ (MJ\ ha^{-1}) - Energy\ input\ (MJ\ ha^{-1})$$

The energy inputs used in wheat production were examined according to different energy norms. Direct energy includes labor and fuel while indirect energy includes fertilizers, pesticides, machinery and seed. Renewable energy resources include labor and seed whereas non-renewable energy sources include fuel, fertilizers, pesticides and machinery (Yılmaz *et al.*, 2010). GHG emission was determined by using the following equation (Hughes *et al.*, 2011).

$$GHG_{ha} = \sum_{i=1}^{n} R\ (i)\ x\ EF(i)$$

GHG_h: Greenhouse gas emission (kg$CO_{2\text{-eq}}$ ha^{-1})

R(i): Amount of i. input (unit$_{input}$ ha^{-1})

EF(i): GHG emission equivalent of i. input (kg$CO_{2\text{-eq}}$ unit$_{input}$$^{-}$)

The GHG ratio is the amount of GHG emissions per unit kg yield and was calculated using the equation below (Houshyar *et al.*, 2015). GHG emission coefficients of the inputs in wheat production are given in Table 2.

$$I_{GHG} = \frac{GHG_{ha}}{Yield\ (kg\ ha^{-1})}$$

Table 2. GHG emission equivalents of the inputs in wheat production.
Çizelge 2. Buğday üretiminde girdilerin sera gazı emisyon eşdeğerleri.

Inputs Girdiler	GHG emission equivalents ($kgCO_{2-eq}$ unit^{-1}) GHG emisyon eşdeğerleri ($kgCO_{2-es}$ birim^{-1})	References Kaynaklar
Labor (h) /İşgücü	0.700	Nguyen and Hermansen, 2012
Machinery (MJ) /Çekigücü	0.071	Pishgar-Komleh *et al.*, 2012
Diesel (l) /Yakıt	2.760	Clark *et al.*, 2016
Nitrogen (kg) /Azot	4.570	Anonymous, 2015
Phosphorus (kg) /Fosfor	1.180	Anonymous, 2015
Herbicides (kg) /Ot ilaçları	23.100	Maraseni *et al.*, 2010
Fungicides (kg) Mantar ilaçları	14.300	Maraseni *et al.*, 2010
Seed (kg) /Tohum	7.630	Clark *et al.*, 2016

RESULTS and DISCUSSION

The input usage of the enterprises and the amount of output they obtained were examined and are given in Table 3. When the input usage in wheat production activity was examined, it was determined that 14.40 hours of labor, 9.90 hours of machinery, and 0.90 hours of combine were used per hectare in the enterprises that had soil analysis. In addition, it was determined that 74.20 l of diesel, 208.80 kg of nitrogen, 47.60 kg of phosphorus, 1.50 kg of herbicide, 3.30 kg of fungicide, and 222.50 kg of seeds were used per hectare. On the other hand, it was determined that 17.30 hours of labor, 11.70 hours of machinery, and 1.10 hours of combine were used per hectare in the enterprises that did not have soil analysis, and it was determined that 81.00 l of diesel, 221.10 kg of nitrogen, 51.00 kg of phosphorus, 1.50 kg of herbicide, 3.50 kg of fungicide, and 217.30 kg of seeds were used. When the amounts of output obtained were examined, the average yield per hectare was found to be 4646.70 kg in the enterprises conducting soil analysis, and 4340.20 kg in the enterprises not conducting soil analysis, and it was determined that enterprises in both groups obtained 1800 kg of wheat straw from one hectare.

As a result of the statistical analysis, it was determined that the difference between the producer groups was statistically significant in terms of the amount of labor, machinery, combine, fuel, nitrogen and seed inputs used and the yield ($p<0.05$), while the difference between the groups was not statistically insignificant in terms of the amount of phosphorus, herbicides and fungicide inputs ($p>0.05$).

Table 3. The inputs used in wheat production and the amount of output obtained.
Çizelge 3. Buğday üretiminde kullanılan girdiler ve elde edilen çıktı miktarları.

Inputs /Girdiler	Soil analysis Toprak analizi yaptıran	No soil analysis Toprak analizi yaptırmayan
Labor (h) /İşgücü	14.40	17.30
Machinery (h) /Çekigücü	9.90	11.70
Combine (h) /Biçerdöver	0.90	1.10
Fuel (l) /Yakıt	74.20	81.00
Fertilizer (kg) /Gübre		
Nitrogen /Azot	208.80	221.10
Phosphorus /Fosfor	47.60	51.00
Pesticides (kg) /Tarım ilaçları		
Herbicides /Ot ilaçları	1.50	1.50
Fungicides /Mantar ilaçları	3.30	3.50
Seed (kg) /Tohum	222.50	217.30
Outputs / Çıktılar		
Wheat (kg) /Buğday	4646.70	4340.20
Wheat straw (kg)/ Buğday samanı	1800.00	1800.00

The energy equivalents of the inputs used in wheat production and the outputs are given in Table 4. The total energy input was 23652.88 MJ in the enterprises that had soil analysis. Among all the energy sources used in production, fertilizers had the highest share with 55.74%. Among fertilizers, nitrogen was in first place with 53.50%. Fertilizers were followed by seeds with 18.90% and fuel inputs with 17.66%. The ratios of pesticides, machinery, combine and labor in total energy were calculated as 4.52%, 2.71%, 0.33% and 0.12%, respectively.

The total energy input in wheat production was 24897.61 MJ in the enterprises that did not have soil analysis. Among all the energy sources used in production, fertilizers had the highest share with 56.10%, and nitrogen was the first among fertilizers with 53.82%. Fertilizers were followed by fuel with 18.32% and seed inputs with 17.54%. The ratios of pesticides, machinery, combine and labor in total energy were calculated as 4.47%, 3.04%, 0.39% and 0.14%, respectively. In the studies conducted by Oren and Ozturk (2006), Shahin *et al.,* (2008), Tipi *et al.,* (2009), Gökdoğan and Sevim (2016), and Abbas *et al.,* (2017), it was determined that among all energy sources used in wheat production, chemical fertilizers had the highest share and it was similar to the research results presented here.

When the energy output was examined, it was seen that 83844.22 MJ energy output was obtained in the enterprises that had soil analysis and 79406.10 MJ in the enterprises that did not have the analysis.

Energy efficiency coefficients in wheat production are given in Table 5. The energy use efficiency found by the ratio of the energy equivalent obtained from wheat production to the energy inputs used was found as 3.54 in enterprises that had soil analysis and 3.19 in enterprises that did not. The energy use efficiency (energy output/input ratio) was found to be more effective in the enterprises that had soil analysis. In the literature, energy use efficiency in wheat production were 2.21 (Oren and Ozturk, 2006), 3.13 (Shahin *et al.*, 2008), 3.09 (Tipi *et al.*, 2009), 1.49 (Ziaei *et al.*, 2015), 1.22 and 1.16 (Kardoni *et al.*, 2014), 2.97 (Gökdoğan and Sevim, 2016), 2.36 (Yıldız, 2016), and 1.59 (Abbas *et al.*, 2017). It was concluded that the energy use efficiency in wheat production was higher in the enterprises that had and did not have soil analysis in this research in comparison with the literature.

Table 4. Energy use in wheat production.
Çizelge 4. Buğday üretiminde enerji kullanımı.

Inputs Girdiler	Soil analysis Toprak analizi yaptıran		No soil analysis Toprak analizi yaptırmayan	
	Energy equivalent (MJ ha-1) Enerji eşdeğerleri (MJ birim^{-1})	%	Energy equivalent (MJ ha-1) Enerji eşdeğerleri (MJ birim^{-1})	%
Labor /İşgücü	28.22	0.12	33.91	0.14
Machinery /Çekigücü	641.52	2.71	758.16	3.04
Combine /Biçerdöver	78.87	0.33	96.39	0.39
Fuel /Yakıt	4178.20	17.66	4561.11	18.32
Fertilizer /Gübre	13184.02	55.74	13967.31	56.10
Nitrogen /Azot	12653.28	53.50	13398.66	53.82
Phosphorus /Fosfor	530.74	2.24	568.65	2.28
Pesticides /Tarım ilaçları	1069.80	4.52	1113.00	4.47
Herbicides /Ot ilaçları	357.00	1.51	357.00	1.43
Fungicides /Mantar ilaçları	712,808	3.01	756.00	3.04
Seed /Tohum	4472.25	18.90	4367.73	17.54
Total /Toplam	23652.88	100.00	24897.61	100.00
Outputs /Çıktılar				
Wheat /Buğday	67284.22		62846.10	
Wheat straw / Buğday samanı	16560.00		16560.00	
Total /Toplam	83844.22		79406.10	

Energy efficiency was calculated as 0.20 kg MJ^{-1} in the enterprises that had soil analysis and 0.17 kg MJ^{-1} in the enterprises that did not have analysis. This coefficient, which expresses the amount of product obtained per energy use, was more advantageous for wheat production in the enterprises that had soil analysis. Specific energy refers to the amount of energy used per product. The specific energy of wheat was calculated as 5.09 MJ kg^{-1} in the enterprises that had soil analysis, and the specific energy of wheat was calculated as 5.74 MJ kg^{-1} in the enterprises that did not have analysis. In this case, the amount of energy required to produce one kg of wheat was 5.09 MJ in the enterprises that had soil analysis, which was seen as more advantageous. The net energy, in which the difference between the energy used and the energy output was expressed, was 60191.34 MJ in the enterprises that had soil analysis, 54508.49 MJ in the enterprises that did not have analysis, and wheat cultivation was more advantageous in enterprises that had soil analysis.

The distribution of the inputs used in wheat production by energy sources is given in Table 6. While the share of direct energy in the total energy inputs was 17.78% and the share of indirect energy was 82.22% in the enterprises that had soil analysis, these rates were determined as 18.46% and 81.54%, respectively, in the enterprises that did not have soil analysis. Indirect energy sources mostly consist of chemical fertilizers, and since the use of fertilizers was more controlled in the enterprises that had soil analysis, the share of indirect energy in total energy was lower in this group. Unconscious use of pesticides and fertilizers causes both losses of inputs and adverse environmental effects.

The share of renewable energy sources in total energy inputs was 19.03% in the enterprises that had soil analysis, and 17.68% in enterprises that did not have. The share of non-renewable energy resources was found to be 80.97% in the enterprises that had soil analysis and 82.32% in the enterprises that did not. Since non-renewable energy resources are limited and harmful to the environment, it can be considered as an advantage that this rate was slightly lower in the enterprises that had soil analysis.

Table 5. Energy analysis of wheat production.
Çizelge 5. Buğday üretiminin enerji analizi.

Energy parameters Enerji parametreleri	Soil analysis Toprak analizi yaptıran	No soil analysis Toprak analizi yaptırmayan
Total energy input /Toplam enerji girdisi	23652.88	24897.61
Total energy output /Toplam enerji çıktısı	83844.22	79406.10
Energy output/input ratio /Enerji çıktı/girdi oranı	3.54	3.19
Energy productivity /Enerji verimliliği	0.20	0.17
Specific energy /Spesifik enerji	5.09	5.74
Net energy /Net enerji	60191.34	54508.49

Table 6. Distribution of the inputs used in wheat production by energy sources.
Çizelge 6. Buğday üretiminde kullanılan girdilerin enerji kaynaklarına göre dağılımı.

Energy resources Enerji kaynakları	Soil analysis Toprak analizi yaptıran		No soil analysis Toprak analizi yaptırmayan	
	MJ ha^{-1}	%	MJ ha^{-1}	%
Direct energy /Doğrudan enerji	4206.43	17.78	4595.02	18.46
İndirect energy /Dolaylı enerji	19446.46	82.22	20302.59	81.54
Renewable energy /Yenilenebilir enerji	4500.47	19.03	4401.64	17.68
Non-renewable energy /Yenilenemeyen enerji	19152.41	80.97	20495.97	82.32
Total /Toplam	23652.88	100.00	24897.61	100.00

The results of GHG emissions of wheat production are shown in Table 7. The total GHG emissions were calculated as 3055.92 and 3109.65 $kgCO_{2-eq}$ ha^{-1} for the wheat production in the enterprises that had and did not have soil analysis, respectively. The results showed that in both groups in wheat production, the share of seed in total GHG emissions was the highest, followed by nitrogen and diesel. The shares of the other inputs in total GHG emissions were around 1.5% and lower when compared with the other inputs. The results of the distribution of the inputs in total GHG emissions showed that the share of human labor was the lowest (0.33% and 0.39%, respectively) for wheat production.

GHG ratios per kg were found as 0.66 and 0.72 for the wheat production in the enterprises that had and did not have soil analysis, respectively. Wheat production in the enterprises that had soil analysis seemed to be more advantageous in terms of GHG consumption when compared with the other producer group.

According to the results of the soil analysis, the yield increases as the plant receives the fertilizer it needs, and the profit of the producer increases with the increase in yield. As a result of the analysis, it was determined that the energy use efficiency and energy productivity were higher, and the specific energy and GHG ratio were lower in the producer group who had soil analysis (Figure 1). These results revealed the importance of having soil analysis and applying the amount of fertilizer according to the soil analysis results.

Table 7. Total GHG emission in wheat production (kgCO_{2-eq} ha^{-1}).
Çizelge 7. Buğday üretiminde toplam sera gazı emisyonu (kg$CO_{2-eş}$ ha^{-1}).

Inputs /Girdiler	Soil analysis Toprak analizi yaptıran		No soil analysis Toprak analizi yaptırmayan	
	GHG emission GHG emisyonu	%	GHG emission GHG emisyonu	%
Human labor (h) /İşgücü	10.08	0.33	12.11	0.39
Machinery (MJ) /Çekigücü	51.15	1.67	60.67	1.95
Diesel (l) /Yakıt	204.79	6.70	223.56	7.19
Nitrogen (kg) /Azot	954.22	31.23	1010.43	32.49
Phosphorus (kg) /Fosfor	56.17	1.84	60.18	1.94
Herbicides (kg) /Ot ilaçları	34.65	1.13	34.65	1.11
Fungicides (kg) /Mantar ilaçları	47.19	1.54	50.05	1.61
Seed (kg) /Tohum	1697.68	55.55	1658.00	53.32
Total /Toplam	3055.92	100.00	3109.65	100.00
GHG ratio (per kg) /GHG oranı (kg başına)	0.66		0.72	

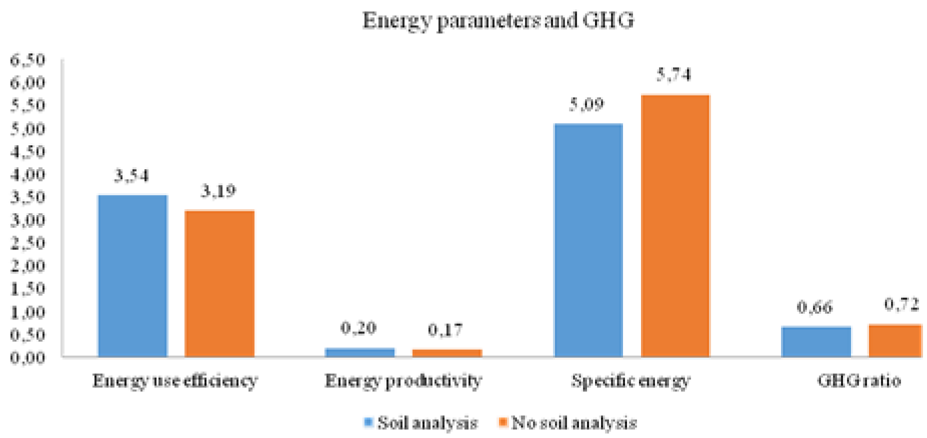

Figure 1. Energy parameters and GHG ratio of wheat production.
Şekil 1. Buğday üretiminde enerji parametreleri ve GHG oranı.

CONCLUSION

In this study, wheat production was examined in terms of energy use and GHG emissions in enterprises that had soil analysis and did not have soil analysis in Edirne. When the energy inputs were analyzed, it was seen that the highest share belonged to chemical fertilizers, and this ratio was higher in the enterprises that did not have soil analysis. In the context of sustainable environment and energy use, it should be considered important for the producers to fertilize according to the technique after the soil analysis was done in the use of fertilizers. In addition, applying different tillage methods in order to reduce fuel-oil input may be beneficial in terms of energy use.

Balanced fertilization programs based on soil analysis play an important role in reducing GHG emissions resulting from agricultural activities. Soil analysis application by the producers should be seen not as a tool but as a goal, and for this, it is important to increase the necessary training and extension services. In addition, a support model should be developed to ensure that soil analysis is mandatory.

Since fertilizers and pesticides cause health effects and greenhouse gas emissions, reducing their use and providing the required minerals to the soil through compost is a very important strategy for improving the soil and increasing its carbon sequestration capacity.

ACKNOWLEDGEMENT

This study was prepared from the project "Evaluation of Fertilizer Use Behaviors of Farmers Based on Soil Analysis in Edirne and Tekirdağ Provinces and Developing Suggestions Based on Soil Analysis Support" supported by the Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies, Türkiye.

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