FEB - FRESENIUS ENVIRONMENTAL BULLETIN
Founded jointly by F. Korte and F. Coulston
Production by PSP - Vimy Str. 1e, 85354 Freising, Germany in
cooperation with PRT-Parlar Research & Technology
Vimy Str 1e, 85354 Freising
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Printed in Germany-ISSN 1018-4619

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A CASE STUDY OF ENERGY BALANCE AND ENERGY ECONOMICS ANALYSIS OF IRRIGATED WHEAT PRODUCTION IN TURKEY

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ABSTRACT

This study was carried out to evaluate the energy balance and energy economics analysis in wheat production. The data were collected randomly from 156 farmers growing irrigated wheat in Erzurum province through a survey during the period of September-November, 2017. According to the results of the study, total energy input and output in wheat production were determined as 20105.9 MJ ha^{-1} and 85703.5 MJ ha^{-1} respectively. Nitrogen source, followed by seeds (17.6%) and diesel fuel (15.7%), had the maximum share of energy input (42.0%). The total energy value from wheat and straw were 85703.5 MJ ha^{-1}; 40.9% of which energy obtained from wheat and 59.1% from straw. In this study, the energy efficiency coefficient was found as 4.26, the specific energy coefficient as 8.43, the energy productivity coefficient as 0.12, and the total energy input cost per hectare as 1752.3 Turkish Liras for wheat production in irrigated conditions. The highest costs per energy units were labor (3.82 TL MJ^{-1}), chemical (insecticide - 0.51 TL MJ^{-1}) and machine (0.16 TL MJ^{-1}) respectively. The average cost of energy input was determined as 0.09 TL MJ^{-1}, and according to the sources, the lowest energy costs were nitrogen (0.02 TL MJ^{-1}), irrigation water (0.04 TL MJ^{-1}) and diesel fuel (0.08 TL MJ^{-1}). The energy benefit-cost ratio was 2.71, gross income was 4755.6 TL per hectare and net income was 3002.7 TL.

KEYWORDS:
Energy economics, wheat, Erzurum, Turkey

INTRODUCTION

Wheat is a traditional and strategic product for Turkey agriculture in terms of production and consumption. In Turkey, wheat is grown in 33% area of the total cultivable agricultural area and in 67.5% of cereal sowing area. Wheat can be produced in almost all regions of Turkey, and more than 3 million farmers are sow wheat each year.

Wheat cultivation areas have ranged between 7.5-8.5 million hectares and the production amount has varied between 17.2-22.6 million tons in the last decade. In the year 2016, total wheat production was 20.6 million tons. According to TUIK data for wheat consumption of our country in 2014/15 season, 15 million 604 thousand tons of wheat was consumed as food, 1 million 425 thousand tons were used as seed, and 2 million 556 thousand tons as animal feed [1].

Agriculture is an energy consumer as well as an energy supplier in the form of bio-energy. Energy is an important input for all agricultural production. It directly uses as fuel for heating or cooling and lighting purposes, and indirectly farm-produced fertilizers and chemicals.

In Turkey agriculture, the mainly consumed energy sources are oil, electricity, natural gas, geothermal and others. In recent years, the oil and electricity consumption per unit of cultivated field area has been 0.185 TOE ha^{-1} (TOE: Tons of Oil Equivalent) and 0.302 MWh ha^{-1}, respectively in Turkey agriculture [2].

In most of the intensive agricultural production systems, energy inputs have been increased to either maximize yields or minimize intensive labor practices or both [3].

In recent years, the studies have aimed to raise the efficiency of energy use in agriculture. In terms of energy, agricultural activities that can be done physically and economically effectively will be sustainable. The practices of sustainable agricultural production depend on improving the efficiency policies with the energy balance analysis of the production activity. In different parts of the world, energy studies have been conducted on different agricultural products [3-15].

Although wheat is one of Turkey's most important agricultural products, the studies that investigated energy efficiency of wheat production are limited. The aim of this study is to evaluate the energy balance and energy economic analysis in wheat production.

TABLE 1
Energy equivalents of inputs and outputs in wheat production

Input	Unit	Energy Equivalent (MJ unit^{-1})	References
Human Labor	h	1.96	[9, 14, 16]
Machinery	h	62.7	[9, 10, 16]
Nitrogen (N)	Kg	66.14	[6, 9, 10, 16]
Phosphorus (P_2O_5)	Kg	12.44	[8-10, 16]
Herbicides	Kg	238	[9, 10, 16]
Seeds	Kg	15.7	[14]
Diesel-oil	L	56.31	[9, 10, 12, 16]
Water for irrigation	m^3	0.63	[9, 10, 16]
Output			
Wheat grain	Kg	14.7	[14]
Wheat straw	Kg	13.75	[17]

MATERIALS AND METHODS

Method and Data Collection. Wheat production technology in Erzurum represents the wheat farming of Turkey. The average yield of wheat in the region is close to the average of Turkey.

The data of the study were randomly collected through a survey from 156 farmers growing irrigated wheat in Erzurum province between September-November, 2017. Seed, fertilizers, chemicals, water, human labor, machinery, and fossil fuels were recorded as inputs, and the main product and by-products were noted as outputs for the farms. In order to determine the energy benefit-cost analysis, data related to costs of inputs and returns of the products were also collected.

The physical units of agricultural inputs were transformed to energy units. The energy equivalents of agricultural inputs in wheat production are given in Table 1.

Energy balance. The energy sources used in wheat production were calculated as both direct and indirect interventions. In agricultural sector, direct and indirect energy types based on the available sources are widely used. The direct energy sources consist of manpower, animal power, fossil fuels, electricity; while indirect energy sources comprise seeds, chemicals, pesticide, fertilizer, farmyard manure, and machinery. They can be divided into three subgroups as physical, chemical and biological sources. The physical energy is a kind of energy that is provided when operating machinery and equipment during agricultural activities. Chemical energy is an energy that is provided by chemical fertilizers, pesticides, herbicides, and fungicides. Biological energy involves the natural energy of seed and hormones. [9, 15, 18-20].

Energy balances estimations for wheat production were performed by using the following criteria [12, 17, 21, 22]:

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

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

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

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

Energy benefit-cost analysis. Modern agriculture requires an energy input at all stages of agricultural production such as direct use of energy in farm machinery, water management, irrigation, cultivation, and harvesting. In addition, there are many indirect or sequestered energy inputs used in agriculture in the form of mineral fertilizers and chemical pesticides, insecticides and herbicides [23]. Energy prices affect the cost of production of agricultural crops. In this study, single crop budget analysis was used to calculate operating costs [9]. Costs and returns of different energy input sources used in wheat production were analyzed to understand the nature of inputs in relation to their energy content. Also, energy benefit-cost ratio was analyzed to reveal the energy efficiency of wheat production. Energy benefit-cost ratio was calculated with the following equation:

$$Energy\ benefit - cost\ ratio = \frac{Gross\ returns\ (TL/ha)}{Total\ costs\ (TL/ha)}$$

In the calculation of net returns, expenditure items such as land lease and interest were not taken into consideration. Gross returns were calculated by multiplying the yield (kg) with the average price and

by taking the main product and the by-product into account. Net returns over variable costs are calculated by subtracting total variable input costs:

$$Net\ returns\ (TL/ha) = Gross\ returns\ (TL/ha) - Cost\ of\ input\ (TL/ha)$$

RESULTS AND DISCUSSION

Energy input and total energy outputs of wheat production are presented in Table 2. In Erzurum region, soil preparation for wheat production begins before the second half of August. In September, second-class tillage equipment is used for replenishment and planting. The first plowing is made with a plow; the second one is with a cultivator, harrow or combined harrow. Sowing in all of the surveyed enterprises is made by seeder. Harvest starts as of July. Fertilizing is done by hand, spraying is done with a sprayer. In irrigated conditions of Erzurum, 39 hours of human labor and 17.9 hours of machine power are used for wheat production per hectare. In the same region and production conditions, 127.8 kg nitrogen, 65.3 kg phosphorus, 56.1 liters diesel fuel, 225.4 kg seeds and 4039.4 m^3 irrigation water is used per hectare.

The total energy input and output were 20105.9 MJ ha^{-1} and 85703.5 MJ ha^{-1} for wheat production, respectively. Safa, Samarasinghe [13], carried out in irrigated conditions of New Zealand, expressed that the maximum energy input was 29693 MJ ha^{-1} and minimum energy input was 20212 MJ ha^{-1} for wheat production. In a study in Iran on wheat production, Ghorbani, Mondani [24] indicated the total energy input was 45367.63 MJ ha^{-1}, the total output energy was 65336.32 MJ ha^{-1}. On the other hand, Ziaei, Mazloumzadeh [25] determined the energy input as 32492.97 MJ ha^{-1} and energy output as 48517.24 MJ ha^{-1}.

In wheat production, 83.9% of the total energy use is obtained from indirect energy sources, while 16.1% is obtained from direct energy sources. Under irrigated conditions of Tokat province, the direct energy sources ratio was 23.11% and the indirect energy sources ratio was 76.89% [9]. The percentages of this energy sources in New Zealand were determined as 43% and 57 % respectively [13].

Nitrogen source has the maximum share of energy input (42.0%), which is followed by seeds (17.6%) and diesel fuel (15.7%), the other inputs that have a major share. Cicek, Altintas [9], indicated that the fertilizer, diesel-oil, and seed had a maximum share among energy inputs, respectively, while Ziaei, Mazloumzadeh [25] reported that the diesel fuel, nitrogen, and seed had the highest share among energy inputs, respectively. Ghorbani, Mondani [24], found that the input energy was relatively higher in nitrogen, diesel fuel, and irrigation water than that of others.

TABLE 2
Energy inputs and outputs in wheat production

Item	Unit	Quantity per unit area (Unit ha^{-1})	Total energy equivalent (MJ ha^{-1})	(%)
1.Direct energy	MJ/ha		3 237.7	16.1
Human labor	h	39.0	76.5	0.4
Diesel fuel	L	56.1	3 161.2	15.7
2.Indirect energy	MJ/ha		16 868.2	83.9
a. Physical energy	H		1 119.8	5.6
Machinery	H	17.9	1 119.8	5.6
b. Chemical energy			9 664.8	48.1
Fertilizers	Kg		9 265.0	46.1
Nitrogen	Kg	127.8	8 452.7	42.0
Phosphorus	Kg	65.3	812.3	4.0
Chemicals	L	1.7	399.8	2.0
c. Biological energy			6 083.6	30.3
Seeds	kg	225,4	3 538.8	17.6
Water for irrigation	m^3	4 039.4	2 544.8	12.7
Total energy input	MJ/ha		20 105.9	100.0
3.Energy output				
Wheat	kg	2 386.4	35 080.1	40.9
Straw	kg	3 681.7	50 623.4	59.1
Total energy output	MJ/ha		85 703.5	100.0

TABLE 3
Energy balance of wheat production

Item	Wheat production
Total energy input (MJ ha^{-1})	20 105.9
Total energy output (MJ ha^{-1})	85 703.5
Energy efficiency	4.26
Specific energy (MJ kg^{-1})	8.43
Energy productivity (kg MJ^{-1})	0.12
Net energy (MJ ha^{-1})	65 597.6

In a study, Rahman and Hasan [26] investigated the energy efficiency in wheat production in Bangladesh and found that the energy values of inputs were 5731.7 MJ ha^{-1} for nitrogen, 244.8 MJ ha^{-1} for phosphorus, 844.6 MJ ha^{-1} for machinery, and 2375.0 MJ ha^{-1} for seed. On the other hand, they found the energy from wheat production was 34681.5 MJ ha^{-1}. Singh, Singh [27] reported that 40% of total input energy in agricultural production came from nitrogen. Indeed, in many agricultural products nitrogen has the largest share of the total energy input as it has an effective role on plant growth and total plant yield. Due to non-renewable sources used in the production of nitrogen, it is necessary to consider natural sources of nitrogen (e.g. animal manure) as a substitute. For example, the energy value of 1-ton animal manure is 300 MJ [28] and in terms of input energy, 5 kg nitrogen can equal 1-ton animal manure.

According to the results of this study, total grain yield was 2386.4 kg ha^{-1} and 3681.7 kg ha^{-1} straw in wheat production. The total energy value obtained from wheat and straw was 85703.5 MJ ha^{-1}; 40.9% of this energy was obtained from wheat and 59.1% from straw. Total energy output in wheat production was found 50127.0 MJ by Cicek, Altintas [9], 295286 MJ and 65336.32 MJ by Safa, Samarasinghe [13] and 68872.43 MJ by Singh, Singh [17].

The energy balance for wheat production in irrigated conditions in Erzurum is given in Table 3. Energy balance is important for assessing whether energy used in agricultural production is used effectively or not. The energy efficiency coefficient was found to be 4.26 for wheat production in irrigated conditions. This means 4.26 units of energy is produced for each energy input used in wheat production. Cicek, Altintas [9] determined the energy efficiency coefficient as 3.8 in irrigated conditions of Tokat region. Furthermore, in terms of wheat production, Safa, Samarasinghe [13] determined this value as 11.5; Ghorbani, Mondani [24] as 1.44; and Ziaei, Mazloumzadeh [25] as 1.49. The results of some studies showed that energy efficiency in agricultural production can vary for different agricultural products, and it can also show differences for different regions and ecological conditions [3, 5, 6, 8, 10, 11, 16, 29-31].

In this study, the specific energy coefficient was determined to be 8.43. This coefficient explains the amount of energy that needs to be consumed to produce one kilogram of wheat. Considering the energy value for producing of a kilogram of wheat was 14.7, it can be accepted that an efficient production was achieved in terms of energy use. Ziaei, Mazloumzadeh [25] found the specific energy coefficient was 17.8.

The energy productivity coefficient explains the amount of product that can be produced by a unit energy input. The energy productivity coefficient was found 0.12 in this study, and it means that 0.12 kilograms of wheat can be produced with one unit of energy. According to the results of the same study, carried out in the different regions of the world it was stated that the energy productivity coefficient changed between 0.056 and 0.17 [9, 24, 25]. The net energy amount was determined as 65597.6 MJ ha^{-1} for wheat production in irrigated conditions.

In agricultural production, only the results of the studies considering the amount of energy alone are not sufficient for energy analyses because energy costs should also be assessed. In this context, energy costs in wheat production are presented in Table 4. In irrigated conditions, the total energy input cost per hectare in wheat production was 1752.3 Turkish Liras. The highest cost per energy unit was labor (3.82 TL MJ^{-1}), chemical (insecticide - 0.51 TL MJ^{-1}) and machinery (0.16 TL MJ^{-1}) respectively. The average input energy cost was determined as 0.09 TL MJ^{-1}, and considering the sources, the lowest energy cost was in nitrogen (0.02 TL MJ^{-1}), irrigation water (0.04 TL MJ^{-1}) and diesel fuel (0.08 TL MJ^{-1}).

Energy benefit-cost ratios are shown in Table 5. In this study, for wheat production in irrigated conditions of Erzurum, the energy benefit-cost ratio was 2.71, gross income was 4755.6 TL per hectare and net income (gross margin) was 3002.7 TL. This coefficient explains the gross income for per unit of input energy. Ghorbani, Mondani [24] determined the benefit-cost ratio (1.97) lower than that of our study. The gross income obtained for per unit output energy was 0.06 TL and the net income was 0.04 TL. Gross income per unit input energy was 0.24 TL and net income was 0.15 TL. In other words, in Erzurum irrigated conditions, it requires 100 TL input energy cost in order to get 15 TL net income.

TABLE 4
Costs of energy input sources in wheat production

Source	Energy use (MJ ha^{-1})	Cost of input (TL ha^{-1})	Cost per energy use (TL MJ^{-1})
Human labor	76.5	292.5	3.82
Diesel fuel	3 161.2	266.5	0.08
Machinery	1 119.8	179.0	0.16
Nitrogen	8 452.7	185.3	0.02
Phosphorus	812.3	114.3	0.14
Chemicals	399.8	204.0	0.51
Seeds	3 538.8	405.7	0.11
Water	2 544.8	105.0	0.04
Total	20 105.9	1 752.3	0.09

TABLE 5
Energy benefit-cost ratio for the wheat production

Particulars	Wheat production
Gross returns of output (TL ha^{-1})	4 755.6
Net returns over variable inputs (TL ha^{-1})	3 002.7
Energy benefit-cost ratio	2.71
Return per unit of output energy (TL MJ^{-1})	0.06
Return per unit of input energy (TL MJ^{-1})	0.24
Net return per unit of output energy (TL MJ^{-1})	0.04
Net return per unit of input energy (TL MJ^{-1})	0.15

CONCLUSION

In this study, energy balance and economic analysis of wheat production in irrigated conditions were investigated in Erzurum region. In wheat production, 85703.5 MJ energy output was obtained by using 20105,9 MJ energy input. The highest energy came from nitrogen, seed and diesel fuel. According to the results of this study, the energy efficiency was determined as 4.26 and the benefit-cost ratio as 2.71. When evaluated in terms of variable inputs, wheat production in irrigated conditions can be said to be energy-efficient, and economically profitable. While the level of energy efficiency can be an acceptable level in wheat production, also the environmental cost of the production must be assessed. In wheat production, the non-renewable sources of energy have the highest share, the sustainability of production depend on the cost of ever-rising imported products, like fertilizers and oil.

Effective use of energy is essential for sustainable agriculture. The use of energy in agriculture is increasing day by day as a result of the limited of agricultural land, even more and more decline, and the demand for higher living standards of the societies. With the increasing population, the increase in food demand leads to more intensive use of inputs such as pesticides, insecticides, chemical fertilizers, and machine power. Agricultural production, made with intensive input threatens human and environmental health. In agriculture, effective use of energy will help reduce the environmental problems, stop the destruction of natural resources and the establish a sustainable agricultural structure [16]. Priority should be given to the practices that will increase energy efficiency or the specific energy coefficient. It can be recommended that the nitrogen requirement of the soil should be reduced, appropriate crop rotations should be managed, the use of animal manure as an alternative to nitrogen source should be encouraged, and the optimum use of machinery to reduce fuel consumption should be achieved.

As a result, although agriculture has a small share in national energy consumption, high and unstable energy costs affects sustainability negatively. Energy dependence should be minimized for a sustainable and environmentally friendly agricultural structure.

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Received: **30.01.2018**
Accepted: **28.02.2018**

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