ISSN 2083-1587; e-ISSN 2449-5999
2024,Vol. 28,No.1, pp. 37-49
Agricultural Engineering
www.wir.ptir.org
DOI: 10.2478/agriceng-2024-0004

ANALYSIS OF ENERGY INDICATORS OF DRY FARMING WHEAT PRODUCTION IN NORTHWEST OF IRAN

Peyman Mohammadzadeh[a*], Gholamhosein Shahgholi[b], Mariusz Szymanek[c*], Wojciech Tanaś[d]

[a] University of Mohaghegh Ardabili, Faculty of Agriculture and Natural Resources, Department of Biosystem Engineering, Ardabil, Iran; e-mail: peymanmohammadzadeh131@gmail.com, ORCID 0000-0001-6940-7376
[b] University of Mohaghegh Ardabili, Faculty of Agriculture and Natural Resources, Department of Biosystem Engineering, Ardabil, Iran; e-mail: gshahgoli@yahoo.com, ORCID 0000-0002-9646-9772
[c] Department of Agricultural, Forest and Transport Machinery, University of Life Sciences in Lublin, Poland; e-mail: mariusz.szymanek@up.lublin.pl, ORCID 0000-0002-3337-0337
[d] Department of Agricultural, Forest and Transport Machinery, University of Life Sciences in Lublin, Poland; e-mail: wojciech.tanas@up.lublin.pl, ORCID 0000-0002-9544-8902

* *Corresponding author: e-mail: peymanmohammadzadeh131@gmail.com; mariusz.szymanek@up.lublin.pl*

ARTICLE INFO

Article history:
Received: September 2023
Received in the revised form: December 2023
Accepted: January 2024

Keywords:
dry farming,
wheat,
energy consumption indices,
energy use efficiency

ABSTRACT

Majority of past research on agricultural product production is related with irrigated areas. Thus, the purpose of this study was to evaluate the energy use pattern in wheat production planted as dry farming in Northwest of Iran. Initial data were collected by means of questionnaires from farmers and agricultural experts in the area. Energy use efficiency indices, net energy, specific energy, energy productivity, energy intensiveness and the total input of energy and total output were computed. Analysis of the total input energy showed that fuel and chemical fertilizer had the highest energy consumption, and the seeds, labor work and chemical pesticides had the lowest energy consumption in wheat production. Energy use efficiency and energy productivity of 1.79 and 0.748 kg·mJ^{-1} were obtained, respectively. The total input and output energy were 33927.61 and 60803.81 MJ·ha^{-1}, respectively.

Introduction

Throughout history, humans have always used various amounts and energy sources to meet the basic needs of their lives. Considering factors such as population growth, environmental issues, climate factors, climatic conditions, and depletion of fossil energy sources, it is necessary to be careful about how energy is consumed and required management should take place (Shahgoli et al., 2018). The scarcity of energy resources and on the other hand the increasing demand for energy are leading to the increasing importance of energy consumption management in macro and micro planning in developed and developing countries.

The agricultural section is strategically focused on food security and human survival. Therefore, the famous classical economist Riccardo claimed that agricultural development would help increase overall productivity of the economy and it fundamentally constraints agricultural growth which determines the boundaries of this sector's growth and the need for capital formation for economic development (Shakeri, 2004).

To evaluate the energy balance in agriculture, wheat was considered due to its high consumption and since it is one of the major crops in Ardabil area. Control and management of energy consumption in the production of this product will ultimately be effective in the economical production of its products and greater efficiency. Given Iran's development plans for managing and controlling energy consumption with a view to sustainable agriculture and environmental protection, planning in this area can be effective in enhancing competitiveness in the agricultural department. The average ratio of energy output to input in Ardabil city for irrigated fields is 4.7 and for dryland was 2.04. Also, the highest ratio of energy output to input for irrigated and dryland fields is 7.8 for Kalkhoran and 2.66 for Sardabeh, respectively and the least values of 1.42 and 1.4 belong to the South Foladlou in this area (Mousavizad, 2017).

One of the major goals of agricultural mechanization is to optimize the use of machine power in planting and harvesting crops with regard to energy use efficiency. It should be noted that for development the mechanization growth, the available indicators must first be developed. Complex biological and technological relationships, changes in the agricultural sections are strongly influenced by political, economic, and social conditions of each region, so it is necessary to consider a combination of these factors for energy analysis. Conventional farming systems that rely entirely on energy consumption in the form of different inputs are vulnerable to technological, economic, social, and environmental aspects (Chaudhary et al., 2006).

Energy analysis is essential for proper management of scarce resources to improve agricultural production and thereby identify efficient and economical production activities. Other benefits of energy analysis include identifying the energy consumed at each stage of the production process and identifying the stages that require the least and maximum energy input, providing the basis for conservation of resources as well as assistance in sustainable management and related policies (Chaudhary et al., 2006).

Over time, despite increasing production in modern agricultural systems due to high energy consumption on the farm, many environmental impacts, such as soil structure degradation and erosion, environmental pollution caused by carbon dioxide emissions, food quality decline and their risk of poisoning and high energy costs are created, which in turn reduces the energy use efficiency of these systems compared to traditional systems and causes instability. These adverse effects and the need for more careful management of limited natural resources led to the revival of worldwide organic farming in the 1980 s (Singh, 2006).

The use of agricultural machines is one of the most prominent examples of agricultural development. Part of the increase in agricultural production is attributable to the use of high-performance agricultural machines and equipment. The development of agricultural mechanization in developed countries has been recognized as a key factor in increasing the standard of living of these countries in the 20th century (Reid et al., 2003).

Reducing the need for labor and thus the production costs is an important aspect of agricultural mechanization. In mechanized fields, less labor is needed than in traditional farms. Traditional cultivation is time consuming and expensive, therefore, agricultural mechanization has been used in many parts of the world to improve farmers' income and agricultural economic attraction (Singh, 2006).

Imran Özçatalbaş (2020) stated that wheat is an important agricultural food in Pakistan and is grown in both irrigated and rainfed production systems. They analyzed the energy use efficiency of wheat crop grown in two different production systems using the data collected from wheat farmers of Punjab province of Pakistan through face-to-face interviews. Energy input–output analysis revealed that 49.079 MJ·ha^{-1} input energy is used in irrigated wheat and 31.421 MJ·ha^{-1} in rainfed wheat. The main difference between both production systems was because of irrigation water. Fertilizer has the highest share in the total energy consumption followed by diesel fuel. Energy consumed per kilogram of wheat produced was less in rainfed wheat compared to irrigated. Similarly, energy efficiency values of rainfed wheat were better than irrigated wheat. Cicek et al., (2011) studied the input-output energy consumption of both irrigated wheat and rainfed wheat production in Tokat province (Turkey). The results showed that the amount of energy consumed in the irrigated wheat production was 13 205.90 MJ·ha^{-1} and in the rainfed wheat production was 14 134. 93 MJ·ha^{-1}. The energy input-output ratio for the irrigated wheat was 3.80 and for rainfed wheat was 2.51. The productivity of irrigated and rainfed areas were 3.67 and 2.43, respectively. About 77% of the total energy inputs used in irrigated wheat production was non-renewable and 23% was renewable. About 75% of the total input energy used in rainfed wheat production was non-renewable and 25% was renewable.

In the study, the most energy-consuming inputs for canola production in Golestan province were identified as chemical fertilizers, diesel fuel and electricity, respectively, with energy use efficiency of 3.02 and energy productivity of 0.12 kg·mJ^{-1}. In the study for sunflower production in Golestan province, the energy productivity of 4.52 kg·mJ^{-1}, energy use efficiency of 0.17 and net energy of 33309 MJ·ha^{-1} were reported (Mousavi-Avval et al., 2011a).

In one study, the total energy consumption of soybean was investigated, the total energy input was 8026.2650 MJ·ha^{-1}and the total output energy was 71228.86 MJ·ha^{-1}. Most of the energy was related to diesel fuel with 66.67% of the total energy consumed (Mousavi-Avval et al., 2011b).

In the analysis of input and output energies of peach production in Golestan province, energy productivity and use efficiency respectively were reported to be 0.29 kg·MJ^{-1} and 0.55. Diesel fuel with a share of 26.32% of the total energy input was identified as the most consumed input in the production of this product. The effect of input energy of labors, agricultural machinery, diesel fuel, chemical fertilizer and animal fertilizer on yield was reported to be significant at 5% level (Royan et al., 2012).

The energy consumption of cotton production in Golestan province was studied. The results showed that the total input energy of 28898 MJ·ha^{-1}, diesel fuel and agricultural machinery energy respectively were 45.6% and 15.9%, which were the most consumed energy inputs in production. Energy use efficiency was about 1.58. The results of sensitivity analysis of energy inputs showed that by increasing one megawatt of energy inputs of seed and manure yields respectively increased by 0.29 and 0.22 kg·ha^{-1}. It was also reported that diesel fuel with the highest energy consumption of cotton production alone accounted for about 45.6% of the variable costs (Taheri-Rad et al., 2015).

Golestan province has a major share in the production of shablon plum. The study of energy consumption status and evaluation of indicators in the plum production sections of Golestan province was carried out. The results showed that the input energy was 25870.33 MJ·ha^{-1} and the energy use efficiency was 1.04. Diesel fuel and fertilizers accounted for 33 and 30 percent and were the most consumed energy sources. The impact of these energy inputs on performance was negative. By increasing one megawatt of energy input, the fertilizer energy of plum yield decreased to 0.87 kg·ha^{-1} (Shaghozayi & Nadi, 2016).

There are sufficient studies that investigated different agricultural products in the irrigated areas all over the world. However, the limited research was conducted in energy balance of these products in dry farming, also it should be noted that in the most countries there is no dry farming production method. Dry farming is a common method of agriculture product production in countries like India, Pakistan, Turkey, and Iran. Hence this study intends to analyse the wheat energy balance in the dry farming method. The purpose of this study was to determine the energy consumption and evaluate the input and output energy consumption in dry farming wheat production in northwest of Iran. Identification of the variables involved in energy use efficiency and their promotion and optimization of energy consumption are the main objectives of this study.

Materials and methods

Germi city is one of the cities of Ardabil province in Iran. This city is located in the northwest of the country and north of Ardabil province (38° 50'N, 47° 25 E' and is located 1100 m above sea level). Cereals are the main agricultural products of the county. All above mentioned conditions allow farmers to reach sufficient yields of cereals. Wheat production of Germi is about 70000-140000 tons per year. The total area of agricultural land is 120. 000 hectares in which the study was conducted. The cultivated area of wheat is 67.000 hectares, a part of which is rainfed and the rest is irrigated. About 50% of the city's Gross Domestic Product (GDP) relies on livestock and agriculture, and its red meat and live livestock. Breeding of sheep, goats, cattle, and buffaloes is common. After that wheat production which has great importance in the city economy, crops like lentil, pea, barley, and alfalfa also have significant contribution to the income of the people of the region. The average yearly precipitation of the county is 460 mm, which decreases from east to west and south to north. While minimum precipitation is at north-west in Khan-Mohammad-loo village by 250 mm, whereas maximum rainfall is at Dashdibi village at south-east by 700 mm per year, which is the highest point in Ardabil province. In general, the rainfall in the county is higher than the average rainfall in the country, which is beneficial for farmers to grow crops like cereals, especially wheat, barley, chickpeas, and lentils.

The number of people selected for the study's questionnaire was determined by the Cochran formula (Snedecor & Cochran, 1989). A sample size was calculated using Eq. 1 and 2 and the number of the required questionnaires was 55.

$$n = \frac{Nt^2s^2}{Nd^{2+}t^2s^2} \quad (1)$$

$$d = \frac{t \times s}{\sqrt{n}} \quad (2)$$

where,

n – the size of the sample

N – the size of the statistical population or the number of sugar beet growers

t – acceptable confidence which is obtained from the t-student table, assuming the desired characteristics to be in a normal distribution (1.96 at 95%)

s^2 – the variance estimation of the treated characteristic in the society (the variance of the energy ratio in the researched region was considered)

d – the potential efficiency (half of the confidence interval)

The information was collected through a questionnaire and interviewed by wheat farmers. The questionnaire included questions about inputs and outputs of wheat production. Table 1 presents the dates and ways of performing different operations in wheat production in Germi. The cultivation of this crop starts in the first half of November and the harvest season starts in the second half of June and the harvesting is generally conducted by a combine.

Table 1.
Date and manner of different operations in wheat production

Title		Description of general instructions and recommendations
Land preparation	Wheat fall	The priority is plowing after dry farming at the depth of 20-25 cm and disking after that and in the secondly, shallow soil loosening using a cultivator at the depth of 8-10 cm is recommended.
Planting stage	Seed Selection	It is recommended to use a modified seed suitable for cultivation in temperate dry farming areas.
	Seed rate	Seed rate per unit area generally varies depending on the amount of rainfall, rainfall distribution, soil type, soil preparation quality, planting date, planting method, and cultivar characteristics. In temperate cold regions suitable seed density of 350 grains per square meter, but in the areas with low rainfall and inadequate rainfall distribution, use of 300 grains per square meter is recommended.
	Planting date	From the first half of October to 20th of November it is the best time to plant wheat in temperate climates.
	Depth and method of planting	Deep planting reduces the percentage of germination and reduces the number of plants, which reduces yield. The most suitable planting depth is 4-6 cm in temperate regions. In areas where there is no risk of erosion, flat panting at the depth of 5 cm is a suitable method. In hard, steep ground where soil preparation is poor, deep working drill (rows spacing of 17-20 cm and planting depth of 4-6 cm) is recommended.

Title		Description of general instructions and recommendations
	Chemical fertilizers	The optimal time of application of nitrogen fertilizers varies depending on the distribution and amount of rainfall and is best based on soil testing and recommendation of pure nitrogen zones (two thirds in autumn at planting time and one third if spring rainfall is assured). Phosphorus fertilizers are also recommended based on soil tests and recommended areas in fall, before planting or simultaneously with planting.
Plant protection stage	Weed control	The purpose of weed control in dry farming of wheat is to reduce their population to the extent that it does not damage the crop and does not reduce the quality of the harvested crop. To overcome weeds in dry farming fields, it is recommended to use integrated methods and weed management such as preventing weed infestation and weeding, consuming agricultural machinery before using it, and preventing it from entering the field.
	Pest Control	1. Crop surveillance to control the population of important wheat pests such as: age, aphid, trips, root lice, black beetle, etc. 2. Conservation and protection of parasitoid bees and flies for biological control of pests 3. Chemical control of wheat (mother) pest after fall in early spring
Harvest		The best time to harvest is when the grain moisture is between 12-14%. The use of harvesting machines (combine harvesters or harvesters) accelerates harvesting and improves the quality and quantity.

The information and data required for this research were collected through a questionnaire and completed by farmers in the region. After collecting the data, an average variable is extracted for the region. In the next step, inputs and outputs were converted to units of $MJ \cdot ha^{-1}$ according to the energy equations in Table 2. Excel 2016 software was used for data analysis. In this study we obtained the productivity which represents the relative efficiency of the farmers in that city. Input energy ($MJ \cdot ha^{-1}$) was considered for various input sources including manpower, diesel fuel, chemical fertilizers, pesticides and animal manure. The number of effective fertilizers was calculated according to the study by Erdal et al., (2007). The input and output energy equations are given in Table 2.

Table 2.
Energy equivalent of inputs and outputs in wheat and barley production

Particulars	Energy equivalent	Unit	Reference
Inputs			
Human labor	1.96	$MJ \cdot h^{-1}$	Yilmaz et al., (2005)
Diesel fuel	56.31	$MJ \cdot h^{-1}$	Erdal et al., (2007)
Oil Energy	36.7	$MJ \cdot h^{-1}$	Kitani (1999)
Machinery	62.7	$MJ \cdot h^{-1}$	Karkacier-and Goktolga et al., (2005)
Combine	87.63	$MJ \cdot h^{-1}$	Karkacier-and Goktolga et al., (2005)
Chemical fertilizers			
Nitrogen (N)	66.14	$MJ \cdot kg^{-1}$	Akcaoz et al., (2009)

Particulars	Energy equivalent	Unit	Reference
Potassium (K_2O)	12.44	MJ·kg^{-1}	Akcaoz et al., (2009)
		Chemical	
Herbicide	238	MJ·kg^{-1}	Tzilivakis et al., (2005)
Pesticide	115	MJ·kg^{-1}	Kaltschmitt et al., (1997)
Farmyard manure	0.3	MJ·kg^{-1}	Pishgar-Komleh et al., (2013)
Seeds	20.1	MJ·kg^{-1}	Ghorbani et al., (2005)
		Outputs	
Wheat grain yield	14.48	MJ·kg^{-1}	Ghorbani et al., (2005)
Wheat straw yield	9.25	MJ·kg^{-1}	Ghorbani et al., (2005)

Based on the input and output energy equivalents (Table 2), the most important energy indices including energy use efficiency, energy productivity, specific energy, net energy and energy intensiveness were evaluated. Thus, after determining energy inputs and outputs, energy indices were calculated (Emadi et al., 2016).

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ·ha}^{-1}\text{)}}{\text{Energy input (MJ·ha}^{-1}\text{)}} \tag{3}$$

$$\text{Energy productivity} = \frac{\text{Wheat output (kg·ha}^{-1}\text{)}}{\text{Energy input((MJ·ha}^{-1}\text{)}} \tag{4}$$

$$\text{Net energy} = \text{Energy output (MJ·ha}^{-1}\text{)} - \text{Energy input (MJ·ha}^{-1}\text{)} \tag{5}$$

$$\text{Specific energy} = \frac{\text{Energy input(MJ·ha}^{-1}\text{)}}{\text{Wheat output (kg·ha}^{-1}\text{)}} \tag{6}$$

$$\text{Energy intensiveness} = \frac{\text{Energy input (MJ·ha}^{-1}\text{)}}{10000} \tag{7}$$

In the study of energy current, energy use efficiency is an indicator for evaluating energy productivity in production (Mohammadi et al., 2010). Input energy is divided into direct and indirect, renewable, and non-renewable forms. Indirect energy includes chemical fertilizers, seeds, and machines while direct energy comprises manpower and diesel fuel in the production process (Khojastehpour et al., 2015). In other words, non-renewable energy includes diesel fuel, pesticides and fertilizers, machinery and renewable energy includes manpower, seed, and water (Namdari et al., 2011).

Results and Discussion

The results showed that the total amount of input and output energy wheat production respectively were 33927.615 and 60803.8 MJ·ha^{-1} (Table 3). In the study area, the energy output of grain was higher than that of straw (Table 3). The share of different inputs in energy consumption in wheat production was different. In a similar study by Kazemi & Zare (2014), they reported that the input energy consumption and the total output energy of wheat production in Gorghan were 32098.20 and 93320.42 MJ, respectively, and in Marvdasht fields were relatively higher and the total input and output energy were 41877.81 and 107155 MJ·ha^{-1}.

Fuel consumed a large amount of energy and the average value of consumed fuel in these farms was 273.79 l·ha^{-1} (15755.14 MJ·ha^{-1}) accounts for 46.44% of the total input energy. Excessive fuel use in this area was due to using old vehicles and working them in sloped fields and working in low speeds. Similar results reported by other researchers (Ziaei et al., 2015; Mohammadi et al., 2010). One of the ways to reduce fuel consumption in this area is the use of combinatorics implements. These devices can reduce fuel consumption and the number of vehicles moving on the soil, ultimately reducing the damage to the soil and preventing the depreciation of implements (Ziaei et al., 2015).

A large amount of a chemical fertilizer of 3954 kg·ha^{-1} was consumed, which accounts for a large part of consumed energy (13907.76 MJ·ha^{-1}) and 40.99% of the total wheat production input energy. In wheat cultivation the most used material to produce chemical fertilizers is urea. In other reports, the highest consumption of urea (N) was reported (Ziaei et al., 2015). Given that these areas are significantly fertilized with animal manure every 5 years, the amount of fertilizer used for agricultural land significantly improves the soil organic matter and increases the product rate of the farm.

The total seed consumed in wheat planting at about 157.6 kg·ha^{-1} (3167.76 MJ·ha^{-1}) accounted for 9.34% of the total input energy, followed by the machines (915.24 MJ·ha^{-1}, 2.7%), oil (106.65 MJ·ha^{-1}, 0.31%) and human labor (44.32 MJ·ha^{-1}, 0.13%) and chemical pesticides (30.728 MJ·ha^{-1}, 0.09%). The average yield of grain and straw in wheat fields was 2540 and 1924 kg·ha^{-1}, and the total energy output of wheat fields was 60803.8 MJ·ha^{-1} (Table 3).

Table 3.
Energy equivalent of inputs and outputs in wheat and barley production

Particulars	Unit	Quantity or amount of input per hectare	Total energy equivalents (MJ·ha^{-1})	Percent (%)
		Inputs		
Human labor	h	22.61	44.32	**0.13**
Diesel fuel	l	273.79	15755.14	**46.44**
Oil energy	l	2.9	106.65	**0.31**
Machinery	h	14.59	915.24	**2.7**
Chemical fertilizers	kg	3954	13907.76	**40.99**
Nitrogen (N)	kg	184	12169.76	**35.87**
Potassium (K_2O)	kg	50	622	**1.83**
Farmyard manure	kg	3720	1116	**3.29**
Chemical			30.72	**0.09**
Pesticide	l	0.26	30.728	**0.09**
Seeds	kg	157.6	3167.76	**9.34**
The sum of the input energies, MJ·ha^{-1}			33927.61	
		Outputs		
Wheat grain yield	kg	2540	36753.81	**60**
Wheat straw yield	kg	1924	24050	**40**
The sum of the output energies, MJ·ha^{-1}			60803.81	

In a similar study by Mangafi and Lari (2017) in the wheat fields of Alborz province, the highest energy output of the main grain yield was observed in Nazarabad, 58500 MJ·ha^{-1} and the lowest amount of energy output in Eshtehard, 53950 MJ·ha^{-1}. The amount of input energy was 59109.93 and 52072.58 MJ·ha^{-1} in Eshtehard and Nazarabad. In the study areas, the amount of straw energy was lower than the output energy of grain. In a similar study by Ziaei et al., (2015) on wheat yield in Sistan and Baluchestan province, the total input and output energy respectively were calculated as 32492.97 and 48517.27 MJ·ha^{-1}.

The amount of energy produced by crops in agricultural products is divided into direct and indirect groups, with direct energy including fossil fuel energy, manpower, electricity, and biofuels. Indirect energy consumption refers to the energy consumed in the production of equipment and other consumables in agriculture including machines, pesticides, fungicides, herbicides, animal manure, chemical fertilizers, seed, and irrigation of farms. The rate of elevation of each of the factors can be seen in Table (4), with the highest diesel fuel content and the lowest level of chemical toxins. The results showed that the share of direct and indirect energy in the total wheat production was 47% and 53%.

Table 4.
Consumed direct and indirect energy in wheat production

Type of energy consumed	Energy equivalent (MJ·ha^{-1})	Percent (%)
Direct energy	15906.12	47
Indirect energy	18021.49	53
Total input energy	33927.61	100

Also, the energy consumed can be divided into two groups of renewable energy (Labor, seed, and water) and non-renewable energy (pesticides, fertilizer, fuel, tractor, electricity, machinery, and facilities). For energy consumption indices in wheat fields as shown in Figure 3. The results showed that 13% of the total input energy in wheat cultivation was from renewable sources and the rest were non-renewable. Ziaei et al., (2015) reported that the share of renewable energy as one of the sustainability indicators of agricultural systems is 19.60% and the rest comes from non-renewable sources. In this study, it was found out that the similarity between the results of this study and the mentioned studies is related with a high similarity between wheat crop systems due to a low level of renewable energy which is a consequence of the absence of irrigation in these fields. Because in these areas the crop is irrigated by rainfall and therefore irrigation has no effect on the consumed energy.

Table 5.
Consumed renewable and non-renewable energy in wheat production

Type of energy consumed	Energy equivalent (MJ·ha^{-1})	Percent (%)
Renewable energy	4328.08	13
Non-renewable energy	29599.53	87
Total input energy	33927.61	100

In the research, the energy use efficiency was 1.792, the energy productivity was 0.074 kg·MJ^{-1}, the net energy was 26876.185 MJ·ha^{-1}, the specific energy was 13.357 MJ·kg^{-1} and the energy intensiveness was 3.392 MJ·m^{-2} (Table 6). Energy efficiency for grain production shows the amount of energy used to produce pure grain. In a similar study, Ziaei et al., (2015) reported that the energy use efficiency in wheat and barley fields were 1.49 and 1.94, respectively, and the energy productivity in the mentioned farms was 0.056 and 0.066 kg·MJ^{-1}, respectively. Similar results by Emadi et al., (2016) reported that energy efficiency was 0.155, and 0.174 kg·MJ^{-1} for wheat, production.

Table 6.
Improvement of energy indices for wheat farms

Items	Unit	Value
Energy use efficiency	-	1.79
Energy productivity	kg·MJ^{-1}	0.07
Net energy	MJ·ha^{-1}	26876.18
Specific energy	MJ·kg^{-1}	13.35
Energy intensiveness	MJ·m^{-2}	3.39

In previous studies related to wheat production, energy output / input ratio was calculated 3.13, 2.81, 2.51, 3.3, 4.9, 2.28 and 3.5 by Shahin et al., (2008) 3.13, Marakoğlu and Çarman (2010), Cicek et al., (2011), Ramah & Baali (2013), Baali & Quwerkerk (2005), Moghimi et al., (2013) and Karaağaç et al. (2011). In some previous studies of wheat energy analysis, Tipi et al., (2009), Shahin et al., (2008), Kardoni et al. (2013), Karaağaç et al. (2011) and Moghimi et al. (2013) have calculated that energy analysis in wheat production as presented in Table 7.

Table 7.
In some previous studies of wheat energy analysis

Studies	Yield (kg·ha^{-1})	Total energy input (MJ·ha^{-1})	Total energy output (MJ·ha^{-1})	Output and input ratio
In this study	5237.48	25876.29	76990.96	1.79
Tipi et al., (2009)	4346	20653.54	63886.20	3.09
Shahin et al., (2008)	6357	38356.39	120097.90	3.13
Kardoni et al., (2013)	4285	35605	62989.50	1.76
Karaağaç et al., (2011)	2587.20	16553.94	63886.20	3.09
Moghimi et al., (2013)	5537.50	42998.44	97935.53	2.28

Conclusions

1. Fuel consumption accounts to a large amount of energy use for wheat production in the studied area and the average value of the consumed fuel in these farms was 273.79 l·ha^{-1} (15755.14 MJ·ha^{-1}) and accounted for 46.44% of the total energy input and similar results found by Ziaei et al., (2015). This was due to the use of a relatively old vehicle and working machine in a sloped field at low velocities. One effective recommendation for fuel

consumption reduction is using special machines developed for dry farming and combinatorics.

2. A chemical fertilizer also consumed a large value of 3954 kg·ha^{-1} (13907.76 MJ·ha^{-1}) and accounts 40.99% of the total wheat input energy. The most used chemical fertilizer is urea. It is recommended, that the fertilizer should be added at a relatively low amount in different times.
3. The total seed consumed in wheat planting was 157.6 kg·ha^{-1} (3167.76 MJ·ha^{-1}) accounted 9.34% of the total input energy, followed by the machines (915.24 MJ·ha^{-1}, 2.7%), oil energy (106.65 MJ·ha^{-1}, 0.31%), human labor (44.32 MJ·ha^{-1}, 0.13%) and chemical pesticides (30.728 MJ·ha^{-1}, 0.09%). The average yield of grain and straw in wheat fields was 2540 and 1924 kg·ha^{-1}. The total input and output energies per hectare were 33927.61 and 60803.81 MJ·ha^{-1}, respectively. The energy efficiency was 1.79, the energy productivity was 0.07 kg·MJ^{-1}, the net energy was 26876.18 MJ·ha^{-1}, the specific energy of 13.35 MJ·kg^{-1} and the energy intensity was 3.39 MJ·m^{-2}.

References

Akcaoz, H., Ozcatalbas, O., Kizilay, H. (2009). Analysis of energy use for pomegranate production in Turkey. *Journal of Food and Agricultural Environment*, *7*, 475-480.

Baali, E.H., Quwerkerk, E. V. (2005). Energy balance wheat production in Morocco. Deutscher Tropentag, International Research on Food Security. *Natural Resource Management and Rural Developmen*t, *11*(13), 1-6.

Chaudhary, V. P., Gangwar, B., Pandey, D.K. (2006). Auditing of energy use and output of different cropping systems in India. *Agricultural Engineering International: CIGR Journal*, *8*(1), 1–13.

Cicek, A., Altintas, G., Erdal, G. (2011). Energy consumption patterns and economic analysis of irrigated wheat and rainfed wheat production: case study for Tokat region, Turkey. *Bulgarian Journal of Agricultural Science*, *17*(3), 378-388.

Emadi, B., Nikkhah, A., Khojastehpour, M., Payman, H. (2016). Effect of farm size on energy consumption and input costs of peanut production in Guilan province of Iran. *Journal of Agricultural Machinery*, *5*(1), 217-228.

Erdal, G., Esengün, K., Erdal, H., Gündüz, O. (2007). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. *Energy*, *32*(1), 35-41.

Ghorbani, R., Mondani, F., Aamirmoradi, S., Feizi, H.,Khorramdel, S., Karkacier, O., Goktolga, Z.G. (2005). Input–output analysis of energy use in agriculture. *Energy Conversion and Management*, *46*(9-10), 1513-1521.

Imran, M., Özçatalbaş, O. (2020). Energy Use Efficiency in Irrigated and Rainfed Wheat in Pakistan. Current trends in Wheat research, Edited by Mahmood-ur-Rahman Ansari, Published by Intech Open, DOI: 10.5772/intechopen.95284.

Karkacier, O., Goktolga, Z.G. (2005). Input–output analysis of energy use in agriculture. *Energy Conversion and Management*, *46*(9-10), 1513-1521.

Kaltschmitt, M., Reinhardt, G. A., Stelze, T. (1997). Life cycle analysis of biofuels under different environmental aspects. *Biomass and Bioenergy*, *12*(2), 121-134.

Karkacier, O., Goktolga, Z. G. (2011). A Case Study Investigating Farmers' View Regarding Soil Analysis: Estimates Using a Logit Model. *Journal of Agricultural Science and Technology*, *13*(4), 467-476.

Kardoni, F., Parande, S., Jassemi, K., Karami, S. (2013). Energy input-output relationship and economical analysis of wheat production in Khuzestan province of Iran. International *Journal of Agronomy and Plant Production*, *4*(9):2187-2193.

Karaağaç, M.A., Aykanat, S., Çakir, B., Eren, Ö., Turgut, M.M., Barut, Z. B., Öztürk, H. H. (2011). Energy balance of wheat and maize crops production in Hacıali undertaking. 11th International Congress on Mechanization and Energy in Agriculture Congress, 21-23 September, Istanbul, Turkey, 388-391.

Kazemi, H., Zare, S. (2014). Investigation and comparison of energy flow in wheat fields of Gorgan and Marvdasht townships, *Cereal Research*, *4*(3), 211-227.

Khojastehpour, M., Nikkhah, A., Hashemabadi, D. (2015). A comparative study of energy use and greenhouse gas emissions of canola production. *International Journal of Agricultural Management and Development*, *5*(1), 51-58.

Kitani, O. (1999). Energy and Biomass Engineering. CIGR, Handbook of Agricultural Engineering. 5. ST Joseph, MI: ASAE Publication.

Mangafi, M., Lari, A. (2017). Evaluation and Comparison of Energy Indicators in Wheat Fields of Alborz Provinces. *Iranian Biosystems Engineering*, *47*(4), 779-771.

Marakoğlu, T., Çarman, K. (2010). Fuzzy knowledge-based model for prediction of soil loosening and draft efficiency in tillage. *Journal of Terramechanics*, *77*(3), 173-178.

Mohammadi, A., Rafiee, S., Mohtasebi, S.S., Rafiee, H. (2010). Energy inputs–yield relationship and cost analysis of kiwifruit production in Iran. *Renewable Energy*, *35*(5), 1071-1075.

Moghimi, M.R., Alasti, B.M., Drafshi, M.A.H. (2013). Energy input-output and study on energy use efficiency for wheat production using DEA technique. I*nternational Journal of Agriculture and Crop Sciences*, 2064-2070.

Mousavi Avval, S.H., Rafiee, S., Jafari, A., Mohammadi, A. (2011a). Improving energy productivity of sunflower production using data envelopment analysis (DEA) approach. *Journal of the Science of Food and Agriculture*, *91*(10), 1885-1892.

Mousavi-Avval, S.H., Rafiee, S., Jafari, A., Mohammadi, A. (2011b). Energy flow modeling and sensitivity analysis of inputs for canola production in Iran. *Journal of Cleaner Production*, *19*(13), 1464-1470.

Mousavizad, M. M. (2017). Determination of energy consumption of wheat production and GIS mapping in Ardabil city. MSc thesis, Department of Biosystems Engineering, Faculty of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran.

Namdari, M., Kangarshahi, A. A., Amiri, N. A. (2011). Econometric model estimation and sensitivity analysis of inputs for mandarin production in Mazandaran province of Iran. *Research Journal of Applied Sciences Engineering and Technology*, *3*(5), 464-470.

Pishgar-Komleh, S. H., Omid, M., Heidari, M. D. 2013. On the study of energy use and GHG (greenhouse gas) emissions in greenhouse cucumber production in Yazd province. *Energy*, *59*, 63-71.

Reid, J.F., Schueller, J., Norris, W.R. (2003). Reducing the manufacturing and management costs of tractors and agricultural equipment. *Agricultural Engineering International: the CIGR Journal of Scientific Research and Development*, vol. 5, Invited Overview Paper. Presented at the Club of Bologna meeting November 16, 2003. Bologna, Italy.

Royan, M., Khojastehpour, M., Emadi, B., Mobtaker, H. G. (2012). Investigation of energy inputs for peach production using sensitivity analysis in Iran. *Energy Conversion and Management*, *64*, 441-446.

Shaghozayi, S., Nadi, F. (2016). Energy modeling of plum production in Golestan province. *Iranian Biosystems Engineering*, *47*(3), 549-541. (in Farsi)

Shakeri, A. (2004). The position of the agricultural sector in the process of economic development of the country. *Agricultural Economics and Development*, *12*(4), 136-105.

Singh, G. 2006. Estimation of a mechanisation index and its impact on production and economic factors- A case study in India. *Biosystems Engineering*, *93*(1), 99-106.

Snedecor, G.W., Cochran, W.G. (1989). Statistical analysis methods. Iowa State University Press, Iowa.

Shahgoli, G., Meri, T., Molaie, F., Eskandar, O. (2018). Energy use pattern in production of sugar beet in western Azerbaijan province of Iran. *AgricEngInt: CIGR Journal, 20*(1), 118-127.
Shahin, S., Jafari, A., Mobli, H., Rafiee, S., Karimi, M. (2008). Effect of farm size on energy ratio for wheat production: A case study from Ardabil province of Iran. American-Eurasian Journal of. Agricultural. & Environmental Science, *3*(4):604-608.
Taheri-Rad, A. R., Nikkhah, A., Khojastehpour, M., Nourozieh, S. (2015). Assessing GHG emissions, and energy and economic analysis of cotton production in the Golestan province. *Journal of Agricultural Machinery*, *5*(2), 428-445.
Tipi, T., Çetin, B., Vardar, A. (2009). An analysis of energy use and input costs for wheat production in Turkey. Journal of Food, Agriculture & Environment, *7*(2):352-356.
Tzilivakis, J., Warner, D.J., May, M., Lewis, K.A., Jaggard, K. (2005). An assessment of the energy inputs and greenhouse gas emissions in sugar beet (Beta vulgaris) production in the UK. *Agricultural Systems*, *85*(2), 101-119.
Yilmaz, I., Akcaoz, H., Ozkan, B. (2005). An analysis of energy use and input costs for cotton production in Turkey. *Renewable Energy*, *30*(2), 145-155.
Ziaei, S. M., Mazloumzadeh, S. M., Jabbary, M. (2015). A comparison of energy use and productivity of wheat and barley (case study). *Journal of the Saudi Society of Agricultural Sciences*, *14*(1), 19-25.

ANALIZA WSKAŹNIKÓW ENERGETYCZNYCH W PRODUKCJI PSZENICY METODĄ ROLNICTWA SUCHEGO W REJONIE PÓŁNOCNO-ZACHODNIEGO IRANU

Streszczenie. Większość przeprowadzonych badań dotyczących produkcji produktów rolniczych dotyczy terenów nawadnianych. Dlatego, celem opracowania była ocena wzoru zużycia energii w produkcji pszenicy zasianej jako uprawa sucha w rejonie północno-zachodniego Iranu. Dane wstępne zgromadzono za pomocą kwestionariuszy przeprowadzonych z rolnikami i ekspertami ds. rolnictwa w tym rejonie. Wskaźniki zużycia energii, energia netto, energia właściwa, wydajność energetyczna, intensywność energetyczna oraz całkowity wkład energetyczny oraz całkowite zużycie energii zostały obliczone. Analiza całkowitego wkładu energetycznego wykazała, że paliwo oraz nawozy chemiczne najbardziej pochłaniały energię, a ziarna, praca człowieka oraz pestycydy wykazywały się najniższym zużyciem energii w produkcji pszenicy. Otrzymano odpowiednio wydajność zużycia energii i produktywność energii w wysokości 1,79 oraz 0,748 $kg \cdot mJ^{-1}$. Całkowity energia włożona i wytworzona wynosiły odpowiednio 33927,61 oraz 60803,81 $MJ \cdot ha^{-1}$.

Słowa kluczowe: suche rolnictwo, pszenica, wskaźniki zużycia energii, wydajność zużycia energii