ENERGY AND CO_2 EMISSION ASSESSMENT OF WHEAT *(TRITICUM AESTIVUM* L.*)* PRODUCTION SCENARIOS IN CENTRAL AREAS OF MAZANDARAN PROVINCE, IRAN

PAZOUKI, T. M.[1] – NOURUZI, A. H.[1] – GHANBARI, M. A.[2] – DADASHI, M. R.[1] – DASTAN, S.[3]

[1]*Department of Agronomy, Gorgan Branch, Islamic Azad University, Gorgan, Iran*

[2]*Department of Agronomy, Jouybar Branch, Islamic Azad University, Jouybar, Iran*

[3]*Department of Biosafety, Agricultural Biotechnology Research Institute of Iran (ABRII)*

**Corresponding author*
e-mail: ajamnorozei@yahoo.com

(Received 6th Feb 2017; accepted 5th Jul 2017)

Abstract. Climate change is a global concern and part of it is due to agricultural activities. Therefore, optimizing the agricultural operation is seen as a strategy to alleviate climate change effects. The purpose of this research was energy and carbon dioxide emission assessment in wheat production. To do so, first, six conventional wheat planting fields were identified in the counties of Jouybar, Ghaemshahr and Sari in Iran, in 2015. Then, through improved planting methods (based on growing low-input wheat, designed by researchers) they were compared. The identification of the field was done in a way that covered all main production methods in each county. After that, the improved and conventional methods of planting in the three counties were investigated as four scenarios. The results showed that the average input energy in four scenarios was 11811.61 MJ ha^{-1} where the least input energy in the improved scenario was 11169.72 MJ ha^{-1}. The highest portion of input energy in the four scenarios was of nitrogen fertilizer with average of 4492.14 MJ ha^{-1} and 38.03 per cent of it had the highest rate of CO_2 emission and global warming potential (GWP). Fuel, phosphorus fertilizer, and seed held the next rank of CO_2 emission. The average GWP of wheat production in the four scenarios was 894.07 kg CO_2 per ha^{-1}. The lowest and highest amount of GWP were 710.2 and 933.59 kg CO_2 per ha^{-1} in scenarios I and II, respectively. Moreover, the amount of GWP per energy input unit was the maximum in scenario II and minimum in scenario IV. Furthermore, the improved scenario had the lowest GWP per energy output unit and scenario I achieved the first rank. In general, the amount of GWP has a direct relationship with the method of field management and input consumption.
Keywords: *climate change, cropping system, environment, food security, global warming potential*

Introduction

Taking a look at the statistics and information about the gap between energy consumption in Iran and developed countries, we can see the deficiencies in energy consumption in Iran more clearly. The most important reasons for this are inefficient energy conversion technologies and improper culture of energy consumption. Agricultural production in the 21st century has to go along and result in increased food security and it has to be less dependent on fairly rare resources such as agricultural lands, water, fossil fuel and non-renewable energies (Uphoff, 2012). While modern methods in this area have not been understood completely and are transitioning, their agricultural and scientific justification is being slowly understood. Many achievements have been recorded by making changes and managing plant's growth environment, soil, water and nutrients, and there is a need for more attention from researchers, policymakers and authorities especially for decreasing climate change consequences (Uphoff, 2012). In producing agricultural crops, such as wheat and to do agricultural

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

operations such as ploughing, applying fertilizers, pesticides, planting, irrigation, harvesting, processing and transformation, there is need for some forms of energy (Chauhan et al., 2006). Efficient use of energy in agriculture is an important factor for the development of sustainable agriculture because it brings economic saving, preservation of fossil fuel and reduction in air pollution (Pervanchon et al., 2002). Concerns about preserving fossil fuels, and greenhouse gases emission have led to an increase in studies about energy efficiency in crop production systems (Koga, 2008). Global warming, due to greenhouse gases emission, is one of the most important global environmental challenges. It is endangering the future life on earth (IPCC, 2007a). Agriculture has a considerable role in greenhouse gases emission and, consequently, global warming (Robertson et al., 2000). Reducing the fossil energy consumption in agricultural systems can decrease the consumption of the limited energy resources and contribute to reduction of greenhouse gases emissions (Dalgaard et al., 2001).

In a study to investigate the energy input in wheat production in Gorgan region, Iran, it was observed that among all the direct energy inputs, fuel consumed in agricultural operation had the highest place with an average of 3390 MJ ha^{-1} and the second slot was for supplying electricity with an average of 309 MJ ha^{-1} (Soltani et al., 2013). Tipi et al. (2009), by investigating energy consumption in 97 fields in Marmara state in Turkey, show that wheat production consumes 20653.5 MJ.ha^{-1} among which the fuel energy input has the highest portion of total energy consumption with 45.15 per cent, and after that comes the chemical fertilizer with 34.21 per cent (especially nitrogen fertilizer with 31.77 per cent). By analyzing the energy efficiency in the Mediterranean agriculture systems in a research, it was reported that energy consumption of low input systems had significantly decreased to 30 per cent. The most important input resources in canola production were chemical fertilizers (64.66 per cent), diesel fuel (24.45 per cent) and pesticides 4.14 per cent (Nassi et al., 2011). Furthermore, in a study done by Ghorbani et al. (2011), the amounts of energy input in the low input and high input planting system for wheat were 9354.2 and 45367.6 MJ ha^{-1}, respectively. Koocheki et al. (2011), while investigating the total energy needed in the fields of bean *(Phaseolus vulgaris* L.*)*, lentil *(Lens culiparis* L.*)* and pea *(Cicer arietinum* L.*)* states that the energy inputs in bean and lentil fields were 23666.8 and 14114.79 MJ ha^{-1}, respectively. Also, in the irrigated and rain-fed cultivation of pea, energy input was reported to be 15756.21 MJ ha^{-1} and 2630.12 MJ ha^{-1}, respectively. In studying 13 scenarios of sugar beet production in England, the average of the total GWP was obtained to be 1.25 t eq-CO_2 ha^{-1}. Also the average GWP for production was estimated to be 0.024 t eq-CO_2 t^{-1} which was 0.0062 t eq-CO_2 GJ^{-1} per unit energy output. According to various production conditions in each of the scenarios, it was said that the amount of GWP had a direct relationship with the amount of energy input in sugar beet production (Tzilivakis et al., 2005a). The development of agricultural systems with less input and more efficiency can contribute to reducing CO_2 emission in agricultural section. Agriculture, especially growing wheat, is considered a noticeable factor in the release of greenhouse gases. It is necessary to investigate the wheat production cycle to determine the amount of energy consumed in order to reduce greenhouse gas emission and global warming. Therefore, the aim of this research was to investigate the energy consumption and global warming potential in wheat production fields in the central parts of Mazandaran province in Iran.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Materials and methods

Description of the site

Mazandaran province is located in the north of Iran. The experimental region is geographically situated at 35°, 47' till 36°, 35' N latitude and 50°, 34' till 54°, 10' E longitude. Based on temperature, rain, and topography of the region, this province is divided into two climates of Caspian mild weather and mountain weather. This research was done in the Caspian mild weather comprising the central portion of the province to the northern foothills. As a result of being close to the Caspian Sea on one side and the Alborz mountain range on the other and due to the short distance between the sea and the mountain, this region enjoys a mild temperature which leads to considerable rain. The mean annual rain in the coastal area of the province is 977 mm. The maximum rainfall occurs in fall and the minimum in spring. Hot and humid summers and mild and humid winters are the main characteristics of this type of weather. Therefore, the weather in some parts of this area is similar to that of the Mediterranean. Also, soil properties in each wheat production scenarios in different counties in depth of 0-30 cm are detailed in *Table 1*.

Table 1. *Soil properties in each wheat production scenarios in different counties (0-30 cm)*

Item		Soil texture	EC (dSm^{-1})	pH	Organic matter (%)	P (ppm)	K (ppm)
Scenario I	Field 1	CL	0.64	7.73	1.92	8.2	160
	Field 2	CLS	1.01	7.63	2.04	15.8	174
	Field 3	LCL	0.51	7.76	1.41	15.4	197
	Field 4	SCL	0.45	7.63	1.66	9.2	246
	Field 5	LCL	0.35	7.72	2.11	19.5	401
	Field 6	L	1.40	7.6	4.23	10.5	464
Scenario II	Field 1	SL	0.61	7.62	2.04	13.1	391
	Field 2	C	0.55	7.71	1.34	5.6	234
	Field 3	CS	1.46	7.68	1.81	10.1	219
	Field 4	CS	0.56	6.55	2.61	11.3	220
	Field 5	C	0.52	7.46	2.11	16.3	452
	Field 6	CL	0.50	7.54	2.36	19.9	490
Scenario III	Field 1	CL	0.44	7.75	1.72	6.9	197
	Field 2	C	0.51	7.66	2.04	5.5	238
	Field 3	SCL	0.52	7.65	2.56	6.1	246
	Field 4	CL	0.39	7.77	1.41	11.4	145
	Field 5	CL	0.47	7.72	1.53	12	160
	Field 6	C	0.53	7.40	1.15	4.9	167
Scenario IV		SC	0.66	7.65	2.87	7.2	221

Description of regions and counties under study

The area this research covers includes three central counties of Mazandaran province (Jouybar, Sari, and Ghaemshahr counties), and based on the research method, we tried to investigate the target population through statistics and scientific methods. To do the research, first, 6 fields for conventional planting of wheat for each county were identified in 2015. Then, they were compared to the improved planting method (according to the growing low input wheat developed by the researchers). Identification of the fields was done in a way that covered all main production methods in every county. After that, the improved and conventional methods of planting in the three counties were investigated as four scenarios. The features of the fields and their complementary information are presented in *Table 2*.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Table 2. *Description of each wheat production scenarios in different counties*

Item		Geographical coordinate	Field area (m^2)	Previous crop	Cultivar	Plow (0-30 cm)	Sowing	Base fertilizer	Top dressing 1	Top dressing 2	Harvest
Scenario I	Field 1	0668661/4052568	30000	Wheat	Zagros & Morvarid	13 Nov.	14 Nov.	14 Nov.	13 Mar.	-	13 Jun.
	Field 2	0607173/4061426	10000	Soybean	Morvarid	25 Nov.	27 Nov.	27 Nov.	28 Feb.	6 Apr.	16 Jun.
	Field 3	0669848/4050342	17000	Wheat	Milan	22 Oct.	15 Nov.	15 Nov.	4 Mar.	-	13 Jun.
	Field 4	0666675/4051164	50000	Soybean	Morvarid	19 Nov.	20 Nov.	20 Nov.	22 Feb.	2 Mar.	15 Jun.
	Field 5	0670958/4050633	15000	Wheat	N-80-19	19 Nov.	20 Nov.	20 Nov.	27 Jan.	28 Feb	13 Jun.
	Field 6	0667482/4061342	20000	Wheat	N-87-20	5 Nov.	10 Nov.	10 Nov.	25 Dec.	7 Mar.	14 Jun.
Scenario II	Field 1	0691941/4069600	28000	Soybean	Milan	8 Nov.	10 Nov.	10 Nov.	20 Jan.	26 Mar.	9 Jun.
	Field 2	0690357/4023752	20000	Canola	Morvarid	20 Oct.	6 Dec.	6 Dec.	11 Apr.	-	15 Jun.
	Field 3	0686313/4068679	20000	Soybean	Morvarid	12 Nov.	14 Nov.	14 Nov.	20 Feb.	10 Mar.	11 Jun.
	Field 4	0709467/4020112	12000	Wheat	Shanghai	14 Nov.	8 Dec.	8 Dec.	22 Mar.	-	25 Jun.
	Field 5	0609483/4024139	10000	Tobacco	N-80-19	27 Nov.	13 Nov.	13 Nov.	-	-	13 Jun.
	Field 6	0702365/4004337	25000	Wheat	Morvarid	22 Oct.	15 Nov.	15 Nov.	-	-	19 Jun.
Scenario III	Field 1	0670166/4047796	18000	Soybean	Morvarid	21 Oct.	20 Oct.	20 Oct.	-	-	9 Jun.
	Field 2	0670429/4044302	12000	Wheat	Milan	28 Oct.	7 Nov.	7 Nov.	12 Mar.	-	5 Jun.
	Field 3	0669674/4042423	7000	Wheat	Morvarid	26 Oct.	9 Nov.	9 Dec.	-	-	10 Jun.
	Field 4	0667144/4040329	7000	Wheat	Milan	25 Oct.	18 Nov.	18 Nov.	4 Mar.	-	3 Jun.
	Field 5	0677217/4038681	10000	Wheat	Milan	25 Oct.	1 Dec.	1 Dec.	20 Feb.	-	11 Jun.
	Field 6	0677851/4037577	20000	Wheat	Shanghai	20 Oct.	21 Nov.	20 Nov.	13 Feb.	-	16 Jun.
Scenario IV		0668497/4051722	8400	Wheat	Milan & Morvarid	20 Nov.	21 Nov.	20 Nov.	20 Feb.	12 Mar.	8 Jun.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

All the managerial practices of the chosen fields were being observed by agriculture engineers. In order to collect information from the fields, first, all agricultural practices were divided into eight parts of providing field, planting, fertilizing, preserving the plants, controlling the weeds, irrigating, harvesting, and transportation. Then, with the beginning of every operation, according to temperature fluctuations, information on various production methods and different amounts of input use by farmers of the region was collected. Typical information of agricultural operations such as the commencement date of every operation and the amount of inputs in every stage of work (from planting to harvesting) was collected and recorded by the observers who went to the fields and observed. Moreover, in the improved planting method, the researchers were seeking reduction of input use, environmental damage and also increase in efficiency and its comparison with common methods of planting wheat in the region. The variables investigated in the improved planting method were as follows:

Improved planting method: The operation of field preparation was done only once by the disc with Massey Ferguson 2850 tractor. The planting operation was done by using 200 kg seed ha^{-1} only by the second disc. The varieties of wheat seeds Milan and Morvarid were planted for dry land farming. According to soil analysis, chemical fertilizers N, P and K (92 kg N h^{-1}, 50 kg P_2O_5 h^{-1} and 50 kg K_2O h^{-1}) were applied to the basal. Moreover, 33.33% N was used in basal, 33.33 % N was used in tillering stage and 33.33 % top dressing of N fertilizer was applied in flowering stage. To control the weeds, herbicide Tapic was applied at 1 litre per hectare once on narrow leaf weeds and simultaneously herbicide Granestar at 25 gram per hectare was applied on wide leaf weeds. Protection operation for fighting pests and diseases was done according to recommendations of the region.

Data collection

All the managerial operation in this is research from the primary plowing and preparing soil to harvesting were recorded through field studies. In these investigations, the method of each managerial operation in the fields was determined in each of the phases of preparing soil, planting, cultivating and harvesting. All data about agricultural management including soil preparation (time and number of plowing, disc, etc.), planting time, fertilizer (amount and time of the applied fertilizer), pests, diseases and weeds control, irrigation (number and time of irrigation) and issues about harvesting (harvest time and yield) were collected. At the end of the growing season, the amount of real harvested yield was recorded. To estimate energy consumption and CO_2 emission, the fields under study in each county with improved planting method were taken as scenarios and totally four scenarios were investigated. To estimate the energy of the inputs and agronomic practices, expressed in MJ ha^{-1}. The energy equivalents in *Table 3* were utilized.

All the information about CO_2 emissions due to direct and indirect energy consumption was recorded and collected. After calculating the amount of energy consumed in the experiment, the result got generalized to an area of one hectare. To estimate energy consumption, the amounts of inputs and outputs were determined. To assess the energy input (consumed), all inputs at the time of practicing the agricultural operations changed into their equivalent by using the relationships of energy equivalence (conversion coefficients) extracted from various sources of every agricultural operation. Then, the input energy for each input and operation was calculated (Singh et al., 2007; Soltani et al., 2013). To determine the energy output

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

(produced) obtained from grain and straw, they were changed to their equivalents by using energy equivalence (conversion coefficients) extracted from wheat grain and straw. After that, the total amounts of their input and output energies were calculated separately (Singh et al., 2007; Soltani et al., 2013). With calculation of the total input and output energies, different forms of energy consumption were identified. Direct energy includes fuel and labor. Indirect energy includes seed, fertilizer, pesticides, water and machinery. Moreover, renewable energy includes labor, seed and water used in irrigation. Non-renewable energy includes fuel, fertilizer, pesticides and machinery (Hatirli et al., 2006; Jarvis, 2000; Mandal et al., 2002; Mirin et al., 2001).

Table 3. *Energy content of inputs and outputs. aIncludes energy required for manufacture, repair and maintenance and transportation of machines, ba.i. represents active ingredient*

Inputs	Unit	Energy (MJ/unit)	Reference
Human labor	h	1.96	Johnson et al. (2007)
Wheat seed	kg	15.7	Canakci et al. (2005); Ozkan et al. (2004)
Machinery [a]	h	62.7	Canakci et al. (2005)
N fertilizer	kg N	60.6	Ozkan et al. 2004; Akcaoz et al. 2009
P fertilizer	kg P_2O_5	11.1	Ozkan et al. 2004; Akcaoz et al. 2009
K fertilizer	kg K_2O	6.7	Ozkan et al. 2004; Akcaoz et al. 2009
Diesel	L	38	Soltani et al. (2013)
Electricity	kWh	12.1	Kaltsas et al. (2007)
Insecticide	kg a.i.[b]	237	Rathke and Diepenbrock (2006); Tzilivakis et al. (2005a)
Fungicide	kg a.i.	99	Strapatsa et al. (2001)
Herbicide	kg a.i.	287	Rathke and Diepenbrock (2006); Tzilivakis et al. (2005a)
Outputs			
Wheat grain	kg	14.7	Tipi et al. (2009); Singh et al. (2003)
Wheat straw	kg	9.25	Tabatabaeefar et al. (2009)

Energy assessment indices including energy ratio, energy productivity, specific energy, and net energy yield were calculated for each planting method (Soltani et al., 2013). It has to be mentioned that the described indices have been determined in order to assess the relationship between the total input and output energies which vary according to the type of product, type of soil, the nature of plowing operation for preparing soil, type and amount of chemical fertilizers and manure, cultivation operation, harvest and finally the yield levels (Soltani et al., 2013). The equations of energy indices are:

$$ER = EO/EI \quad \text{(Eq.1)}$$

where:
ER is the energy ratio and is a number without a unit, EO is the total energy output from the field (MJ ha^{-1}), and EI the total energy input to the field.

$$EP = GY/EI \quad \text{(Eq.2)}$$

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

where:
EP is the energy productivity (kg MJ^{-1}), GY is grain yield (kg ha^{-1}) and EI the total energy input to the field (MJ ha^{-1}).

$$SE=EI/GY \quad \text{(Eq.3)}$$

where:
SE is the special energy (MJ kg), EI is the total energy input to the field (MJ ha^{-1}), and GY the grain yield (kg ha^{-1}).

$$NEY=EO-EI \quad \text{(Eq.4)}$$

where:
NEY is the net energy yield (MJ ha^{-1}), EO is the total energy output from the field (MJ ha^{-1}), and EI is the total energy input to the field (MJ ha^{-1}).

In order to calculate the global warming potential, first, the fuel for consumption in the factory and the energy consumed for production and transportation of inputs including chemical fertilizers, pesticide, machinery and fuel consumption for agricultural operations were determined (Green, 1987; IPCC, 2007b, 2007c; Tzilivakis et al., 2005a, 2005b). Then, CO_2 emission for every section was calculated. To calculate carbon dioxide emission from winnowing, disinfection and transportation of the grains, the factor was determined according to the type of agricultural management and grain quality (IPCC, 2007a, 2007d). After calculating the total GWP, estimation of CO_2 emission per unit area (kg eq-CO_2 ha^{-1}), per unit weight (kg eq-CO_2 t^{-1}), per unit of energy input (kg eq-CO_2 GJ^{-1}) and per unit of energy output (kg eq-CO_2 GJ^{-1}) were done (Soltani et al., 2013).

Results

Analysis of energy input and energy output

The mean for total energy input in the four scenarios was 11811.61 MJ ha^{-1}. The lowest energy input was obtained in the improved planting method at 11169.72 MJ ha^{-1}, and scenarios II and III got the next rank with little difference (11261.26 and 11262.21 MJ ha^{-1}, respectively). Scenario I, which is the conventional planting method in Jouybar county, bagged the first place with significant and noticeable difference with 13553.25 MJ ha^{-1} *(Table 4).*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Table 4. *Energy balance (MJ ha^{-1}) for each wheat production scenario. * Scenario IV is improved planting method. Scenarios I, II, and III are conventional method*

Item	Scenario								Mean	Standard error	Share (%)
	I	Share (%)	II	Share (%)	III	Share (%)	IV*	Share (%)			
Input											
Seed	2820.6	21.81	3359.8	29.84	2862.58	25.42	3140	28.11	3045.75	126.41	25.79
Labor	24.65	0.18	20.09	0.18	30.97	0.27	26.42	0.24	25.53	2.25	0.22
Machinery	614.8	4.54	462.73	4.11	600.67	5.33	366.80	3.28	511.25	59.12	4.33
Fuel	3899.7	28.77	3250.14	28.86	3937.94	34.97	1990.44	17.82	3069.56	645.94	25.99
Chemical fertilizer											
N	5358.2	39.53	3561.87	31.63	3473.29	30.84	5575.2	49.91	4492.14	564.69	38.03
P_2O_5	557.4	4.11	455.67	4.05	324.79	2.88	510.6	4.57	462.12	50.27	3.91
K_2O	191.3	1.41	124.82	1.11	9.25	0.08	335	3	165.09	67.99	1.40
Pesticide											
Herbicide	32.7	0.24	19.23	0.17	22.72	0.20	25.26	0.23	24.98	2.86	0.21
Fungicide	9.5	0.07	0	0	0	0	0	0	2.38	2.38	0.02
Insecticide	44.4	0.33	6.91	0.06	0	0	0	0	12.83	10.65	0.11
Total	13553.25	100	11261.26	100	11262.21	100	11169.72	100	11811.61	580.95	100
Output											
Grain	71747.1	39.68	47101.25	31.21	58371.25	34.47	67987.5	36.34	61301.78	5507.92	35.63
Straw	109072.9	60.32	103820	68.79	110973.3	65.53	119093.75	63.66	110740	3168.93	64.37
Total	180820	100	150921.3	100	169344.6	100	187081.3	100	172041.8	28936.55	100

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

By comparing different types of inputs in the four scenario, we see that the percentage of total energy consumed (nitrogen input) with total mean of 4492.14 MJ ha^{-1} (38.03 per cent) is on the top of the chart. The highest amount is for the improved scenario with 49.91 per cent (5572.2 MJ ha^{-1}). Scenario I bags second place with 39.50 per cent (5358.2 MJ ha^{-1}). Other ranks were of scenario II and III with nitrogen inputs of 31.63 and 30.84 per cent (3561.87 and 3473.29 MJ ha^{-1}, respectively). After the energy input of nitrogen, energy input of the fuel (3069.56 MJ ha^{-1} and 25.99 per cent) and seed (3045.75 MJ ha^{-1} and 25.79 per cent) had the highest amount. About the energy of the consumed fuel, scenario III got the first rank with 34.97 per cent of the total input and scenario IV bagged the last rank with 17.82 per cent of the total input. Scenarios I and II with 28.77 and 28.86 per cent of the consumed fuel, got the second and third place. By comparing the four scenarios about the seed consumed, it was seen that the fields of scenario I had the lowest amount with 2820.6 MJ energy (21.81 per cent); scenario III with 2862.58 MJ was placed before it. Scenarios II and IV with the consumption of 3359.8 and 3140 MJ ha^{-1} (29.84 and 28.11 per cent respectively) showed the highest amount of input energy for the seed *(Table 4)*. Findings show that in the region's farming culture, the energy input belonged to the nitrogen chemical fertilizer, fuel and seed. The main reason for this is that wheat production method in the region is traditional. To strong then the field, farmers used great amounts of chemical fertilizers, which utilized in the wrong way without paying attention to organic materials and biological resources.

Other inputs in the fields under study didn't show noticeable measures in different scenarios. The lowest inputs belonged to consuming pesticides. In most fields under study in the four scenarios, farmers did not use insecticides or fungicide. Also, little herbicide was used. The energy input for labor was little considering conversion coefficient. The energy input of machinery with the mean of 511.25 MJ ha^{-1} and 4.33 per cent of the total, got the fourth rank which was higher in scenarios I and III compared to scenarios II and IV. Moreover, the energy input of potassium (K_2O) and phosphorus (P_2O_5) with the means of 462.12 and 165.09 MJ ha^{-1} had 3.91 and 1.4 per cent of the total energy input, respectively *(Table 4).*

An average of the total production energy in the four scenarios was 172041.8 MJ ha^{-1} and 35.63 per cent of it belonged to grain production energy (61301.78 MJ ha^{-1}) while 64.37 per cent of it belonged to straw energy (110740 MJ ha^{-1}). The highest energy production was obtained in the improved planting methods 187081.3 MJ ha^{-1} and 36.34 per cent of it belonged to grain energy (67987.5 MJ ha^{-1}) while 63.66 per cent of it belonged to straw energy (119093.75 MJ ha^{-1}). Scenario I with 180820 MJ ha^{-1} energy output got the second rank which consisted of 39.68 per cent grains (71747.1 MJ ha^{-1}) and 60.32 per cent straw (109072.9 MJ ha^{-1}). The next fields with scenarios II and III got the next places with 150921.3 and 169344.6 MJ ha^{-1}, respectively *(Table 4)*. The main reason for the observed differences between the amount of input energy and output energy in the four scenarios under study is the difference in the ways to manage things and amounts of input consumption.

The highest energy input coming from fuel in the four production scenarios is about land preparation operation where scenario III showed the highest amount of fuel consumption (1649.77 MJ ha^{-1}) and scenarios I and II with the consumption of 1557.6 and 1428.8 MJ ha^{-1} bagged the second and third places, respectively. By managing the field in the improved scenario, energy of the consumed fuel (452.2 MJ ha^{-1}) decreased significantly. After land preparation operation, the harvest operation had the highest

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

amount of fuel input, where scenario III and I (1595.11 and 1313.09 MJ ha^{-1}) were significantly higher than scenarios II and IV (1192.75 and 1187.5 MJ ha^{-1}). Planting operation got the third place with regard to fuel input. It was significantly lower in the improved method than in the other three scenarios. In all four scenarios, the operations of weed control, plant protection, nutrition and transportation got the next places, respectively. Considering that all fields in all four scenarios were dry land planting, no energy input was recorded for irrigation (*Figure 1*).

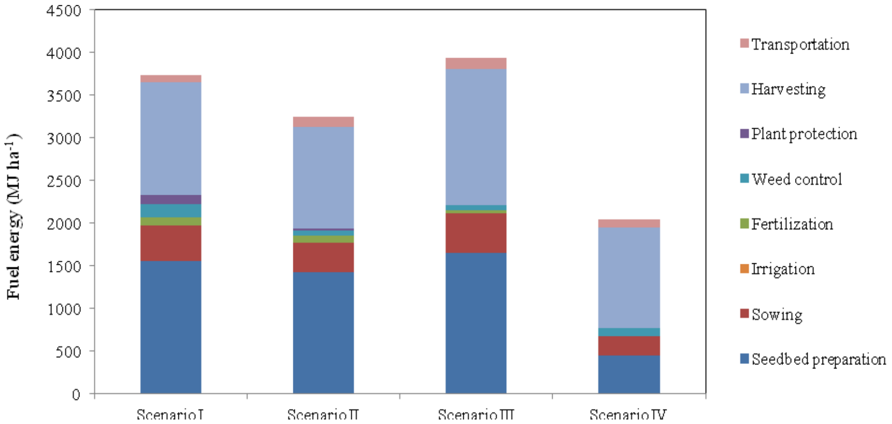

Figure 1. *Energy consumption in fuel in each production operation in each scenario of wheat production. Note that scales are different for the panels*

The energy input of the machinery in different stages of wheat production shows that the biggest part of it in the four scenarios was land preparation which was 284.87, 236.8 and 281.73 MJ ha^{-1} for scenarios I, II and III, respectively. In scenario IV, it was 99.69 MJ ha^{-1}. The operations of planting and harvesting got the next places which were different in different scenarios. Weed control and transportation of the machinery were placed lower. Energy consumption of the machinery for nutrition and protection was little: it was considered zero in the improved scenario. Moreover, because there was no irrigation in the four scenarios, this section did not have an energy input (*Figure 2*).

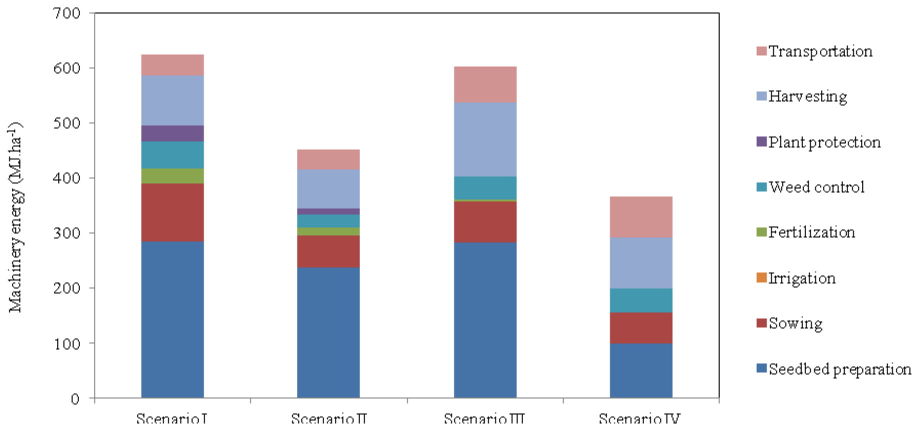

Figure 2. *Energy consumption in machinery in each production operation in each scenario of wheat production. Note that scales are different for the panels*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Most energy for labor was in the scenarios number I to III for land preparation with 8.9, 7.4 and 8.8 MJ ha^{-1}, respectively. But in the improved scenario, the highest amount of labor energy was nutrition and planting (7.78 and 7.58 MJ ha^{-1}, respectively), and land preparation operation (3.12 MJ ha^{-1}) stood in the next place. Labor energy input was not observed in this scenario for protection. Irrigation in scenarios I and II nutrition bagged the second place and planting operation got the third rank. But in scenario III harvesting and planting operation got the next places (*Figure 3*).

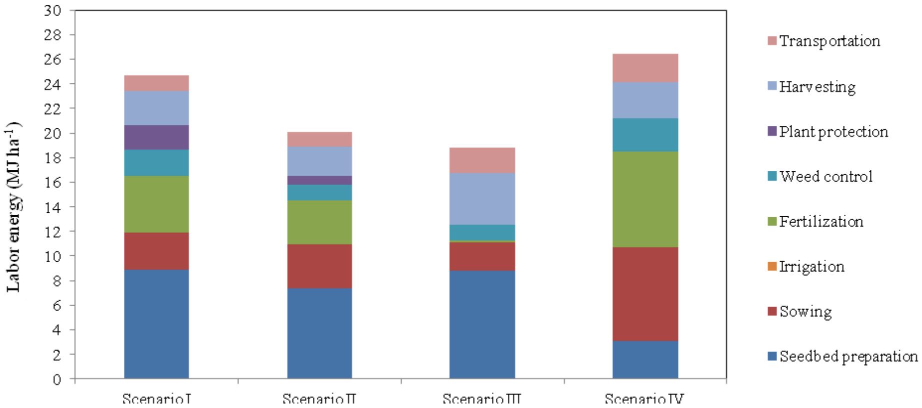

Figure 3. *Energy consumption in labour in each production operation in each scenario of wheat production. Note that scales are different for the panels*

Portions of energy input in wheat production

About different forms of energy, the findings in *Table 5* show that the means for direct and indirect total energy input in the four scenarios were 3295.09 and 8516.52 MJ ha^{-1}, respectively. The highest amount of directly consumed energy was for scenarios III and I with 3968.91 and 3924.35 MJ ha^{-1}. Scenario II with the input of 3270.23 MJ ha^{-1} bagged the third spot and scenario IV with 2016.86 MJ ha^{-1} was at the bottom of the list. Also, the two scenarios I and IV had the highest amounts of indirect energy inputs (9628.9 and 9152.86 MJ ha^{-1}), respectively. The amounts of indirect energy input for scenarios II and III were 7991.03 and 7293.3 MJ ha^{-1}, respectively (*Table 5*). According to the findings in *Table 5*, the means for renewable and non-renewable energy inputs in the four scenarios were 3071.28 and 8740.33 MJ ha^{-1}, respectively. In a group comparison between the two types of renewable and non-renewable energies, it was observed that renewable input energy in scenarios II and IV (3379.89 and 3166.42 MJ ha^{-1}) was more than in scenarios I and III (2845.25 and 2893.55 MJ ha^{-1} of the total consumed energy), respectively.

The lowest non-renewable input energy (7881.37 MJ ha^{-1}) belonged to scenario II and the highest non-renewable input energy (10708 MJ ha^{-1}) belonged to scenario I. Non-renewable energy in scenarios III and IV were 8368.66 and 8003.3 MJ ha^{-1} (*Table 5).*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Table 5. *Energy types and indices for each wheat production scenario. * Scenario IV is improved planting method. Scenarios I, II, and III are conventional method*

Indices	Scenario				Mean	Standard error
	I	II	III	IV*		
Input						
Direct (MJ ha^{-1})	3924.35	3270.23	3968.91	2016.86	3295.09	455.02
Indirect (MJ ha^{-1})	9628.9	7991.03	7293.3	9152.86	8516.52	533.44
Renewable (MJ ha^{-1})	2845.25	3379.89	2893.55	3166.42	3071.28	124.82
Non-renewable (MJ ha^{-1})	10708	7881.37	8368.66	8003.3	8740.33	664.01
Total input (MJ ha^{-1})	13553.25	11261.26	11262.21	11169.72	11811.61	580.95
Output						
Grain yield (kg ha^{-1})	5796.8	3204.2	3970.8	4625	4399.2	548.92
Straw yield (kg ha^{-1})	11791.7	11187.5	11958.3	12875	11953.13	349.06
Total output (MJ ha^{-1}	180820	150921.3	169344.6	187081.3	172041.8	7940.37
Output/input ratio (MJ ha^{-1})	13.34	13.40	15.04	16.75	14.57	0.81
Specific energy (MJ kg^{-1})	0.43	0.28	0.35	0.41	0.37	0.03
Energy productivity (kg MJ^{-1})	2.34	3.51	2.84	2.42	2.68	0.27
Net energy ratio (MJ ha^{-1})	167266.75	139660.04	158082.39	175911.58	160230.19	7762.96

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Analysis of energy indices in wheat production

As shown in *Table 5*, energy ratio was 14.57. The highest energy ratio (16.75) was of the improved scenario and the lowest amounts (13.34 and 13.3) were in case of scenarios I and II. The reason for the low energy ratio can be attributed to their heavy dependence on inputs and use of more energy for production; these inputs are used without considering environmental issues. About the index of energy productivity, research findings showed that the mean for this index in the four scenarios was 0.37 kg MJ^{-1}, the highest amount of which was obtained in scenarios I and IV as 0.43 and 0.41 kg MJ^{-1}, respectively. As for scenarios II and III, the amounts were 0.28 and 0.35 kg MJ^{-1}, respectively (*Table 5*), which were lower than the results of Khan et al. (2010) in Australia. This is probably because of high energy input in Iranian production systems and the region's farming culture. The mean of the specific energy in the four scenarios was 2.68 MJ kg, where scenario II had the highest amount (3.51 MJ kg). The lowest specific energy belonged to scenario I (2.34 kg MJ^{-1}), and for scenarios III and IV it was 2.84 and 2.42 kg MJ^{-1}, respectively *(Table 5)*. Specific energy is the opposite of energy productivity, so its lower mounts show that less energy has been used for production per every unit of yield *(Table 5)*. About productivity and yield of the four scenarios as a system of energy conversion, research findings showed that the mean for net energy index was 160230.19 MJ per hectare. The highest net energy belonged to the improved scenario (175911.58 MJ per hectare) and scenario I (167266.75 MJ per hectare) got the second rank and scenario II (139660.04 MJ per hectare) stood last. Correct management method in the improved scenario and high amounts of inputs led to this result *(Table 5)*.

CO_2 emission and global warming potential

According to the findings in *Table 6*, the mean for the 4 scenarios is 894.07 kg eq-CO_2 ha^{-1}. The lowest amount of global warming potential was for scenario I (710.2 kg eq-CO_2 ha^{-1}) and the highest amount of it was in case of scenario I (equal to 933.59 kg eq-CO_2 ha^{-1}). GWP in scenarios III and IV were 748.66 and 765.78 kg eq-CO_2 ha^{-1}, respectively.

Among different activities, nitrogen energy input got the first place in CO_2 emission and global warming in all scenarios with the average of 327.04 kg eq-CO_2 ha^{-1}, equal to 41.42 per cent. It showed a considerable difference compared to other inputs where the improved scenario stood first with 405.88 kg eq-CO_2 ha^{-1} and scenario I stood second rank with 390.15 kg eq-CO_2 ha^{-1}. Scenarios II and III were in next places with 259.27 and 252.86 kg eq-CO_2 ha^{-1}.

After nitrogen fertilizer, the consumed fuel had the highest CO_2 emission the mean of which in the four scenarios was 254.03 kg eq-CO_2 ha^{-1}, equal to 32.17 per cent, where the improved scenario stood last with 155.25 kg eq-CO_2 ha^{-1}. Scenario III and I got first and second places with 307.17 and 304.17 kg eq-CO_2 ha^{-1} *(Table 6)*. Machinery with average of 63.98 and seed with average of 87.83 kg eq-CO_2 ha^{-1} comprise 8.10 and 11.12 per cent of the total CO_2 emission in the four scenarios. Moreover, global warming potential coming from the use of herbicide had the average of 2.57 kg eq-CO_2 ha^{-1} and 0.33 per cent of the total CO_2 emissions. The portion of other activities in production and transportation of the agricultural inputs was not significant *(Table 6)*. The mean for the global warming potential of all scenarios in the unit of area was 894.07 kg eq-CO_2 ha^{-1} which was minimum in scenario II, III and IV (710.2, 748.66 and 765.78 kg eq-CO_2 ha^{-1}) and maximum in scenarios I (933.59 kg eq-CO_2 ha^{-1}). In the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

same respect, the total amounts of global warming potential in the unit of area for potato, canola, barley and peas were 3, 1.7, 1.2, 0.7 and 0.7 t eq-CO_2 ha^{-1} (Tzilivakis et al., 2005 b). Also, global warming potential in the unit of energy input had mean of 66.75 kg eq-CO_2 GJ^{-1} in the four scenarios which was minimum in scenario IV (68.56 kg eq-CO_2 GJ^{-1}) and was maximum in scenario II (63.07 kg eq-CO_2 GJ^{-1}). The mean of global warming potential in the unit of energy output was 4.94 kg eq-CO_2 GJ^{-1} in the four scenarios. The improved scenario had the least global warming potential in unit of energy output width 4.35 kg eq-CO_2 GJ^{-1} and scenario III stood second with 4.73 kg eq-CO_2 GJ^{-1}. Scenarios I and II had the highest global warming potential in the unit of energy output with 5.58 and 5.08 kg eq-CO_2 GJ^{-1} *(Table 7).* Mean of the global warming potential in the unit of grains' weight in the four scenarios was 184.2 kg eq-CO_2 t^{-1}. The lowest global warming potential in the unit of grains' weight was observed in scenarios I and IV where 161.05 and 165.57 kg eq-CO_2 t^{-1} were obtained. The highest global warming potential was in scenario II which was 221.64 kg eq-CO_2 t^{-1}. Less global warming potential was seen in the units of area and weight in scenarios I and II compared to other two scenarios. This can be attributed to less consumption of energy input and also higher production rate in this planting scenario *(Table 7).* The comparison between energy input and the resulting CO_2 emission in this research showed that there was a direct relationship between energy input and global warming potential in wheat production scenarios *(Figure 4)*, in a way that for every MJ increase in energy input in the four scenarios, CO_2 emission increased 75.1 kg per hectare. Since fossil fuel is important factors in GHG emissions, especially CO_2, appropriate agricultural operations have to be used.

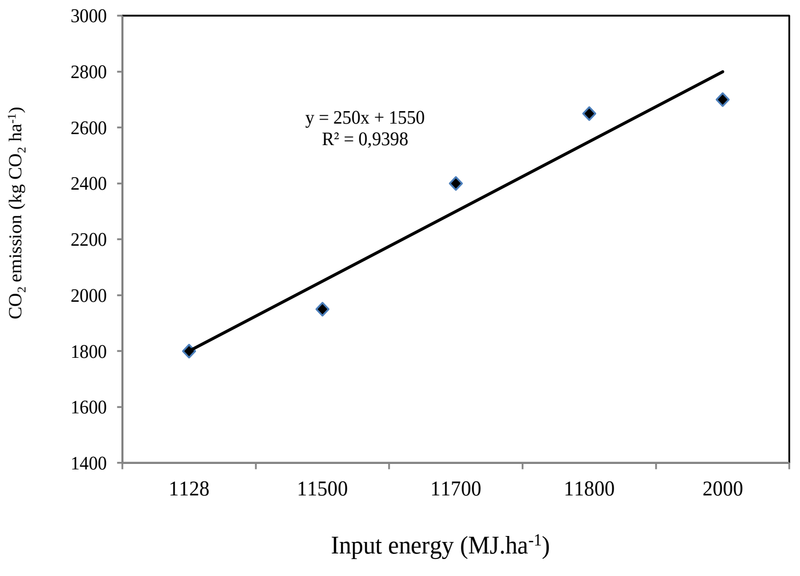

Figure 4. *Liner regression model between input energy and CO_2 emissions in wheat production scenarios*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Table 6. *CO_2 emissions (kg eq-CO_2 ha^{-1}) for each wheat production scenario. * Scenario IV is improved planting method. Scenarios I, II, and III are conventional method*

Item	Scenario								Mean	Standard error	Share (%)
	I	Share (%)	II	Share (%)	III	Share (%)	IV*	Share (%)			
Seed	91.98	9.85	93.07	13.10	79.30	10.59	86.98	11.36	87.83	2.56	11.12
Machinery	76.91	8.24	57.93	8.16	75.18	10.04	45.89	5.99	63.98	6.03	8.10
Fuel	304.17	32.58	249.54	35.13	307.17	41.03	155.25	20.27	254.03	28.98	32.17
Chemical fertilizer											
N	390.15	41.79	259.27	36.51	252.86	33.77	405.88	53	327.04	33.58	41.42
P_2O_5	46.04	4.93	64/37	5.30	26.83	3.58	42.18	5.51	38.17	3.39	4.84
K_2O	15.42	1.65	10.06	1.42	5	0.67	27	5.53	14.37	3.85	1.82
Pesticide											
Herbicide	3.37	0.36	1.98	0.28	2.34	0.31	2.60	0.34	2.57	0.24	0.33
Fungicide	0.98	0.11	0	0	0	0	0	0	0.25	0.20	0.03
Insecticide	4.58	0.49	0.71	0.1	0	0	0	0	1.32	0.89	0.17
GWP	933.59	100	710.2	100	748.66	100	765.78	100	894.07	40.33	100

Table 7. *Global warming potential equal to kg CO_2 emission per unit area, per unit weight, per unit input and output energy for each wheat production scenario. * Scenario IV is improved planting method. Scenarios I, II, and III are conventional method*

GWP	Scenario				Mean	Standard error
	I	II	III	IV*		
Per unit area (kg eq-CO_2 ha^{-1})	933.59	710.20	748.66	765.78	894.07	40.33
Per unit weight (kg eq-CO_2 t^{-1})	161.05	221.64	188.54	165.57	184.20	13.86
Per unit energy input (kg eq-CO_2 GJ^{-1})	68.88	63.07	66.48	68.56	66.75	1.33
Per unit energy output (kg eq-CO_2 GJ^{-1})	5.58	5.08	4.73	4.35	4.94	0.26

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

Discussion

The results showed that non-renewable energies have little portion in the region. This issue is ecologically important because the source of non-renewable energy is generally fossil fuel, and relying on this recourse can bring danger in the future. Research findings show that agriculture in Iran heavily depends on non-renewable energy (Beheshti et al., 2010). High consumption of non-renewable energy decreases the energy productivity of production systems because producing chemicals and using machinery as the main indices of current systems requires the consumption of a lot of energy. In this research the portion of indirect energy is bigger than that of direct energy and the portion of non-renewable energy is higher than that of renewable energy. According to Moore (2010), in order to reach a sustainable production system, we have to increase the energy productivity and portion of renewable energy in the ecosystems. However, nowadays supplying food to the growing population of the world without non-renewable energy seems difficult or perhaps impossible. Therefore, considering the consequences of using chemicals and fossil fuel, agriculture experts will have no other options than think about increasing the sustainability in agriculture and the portion of renewable energy in production systems.

Agriculture is the system of energy conversion; it converts some commercial and non-commercial energy sources into products containing energy which is usable by humans (Kizilaslan, 2009), yield and productivity of this conversion are accessed through indices such as energy ratio, energy productivity and net energy. Energy ratio in Australian and Indian rice planting systems appears to be similar (Khan et al., 2010). According to the results obtained, we can increase energy productivity by decreasing fuel consumption, mechanization and machinery. Moreover, energy consumption decreases when energy resources are used more effectively through optimization of different types of the inputs by choosing the right type, amount, method and time of using the inputs such as chemical pesticides and fertilizers. A research study investigated energy consumption in 97 wheat fields in Marma state, Turkey, and it was observed that wheat production consumed 20653.5 MJ per hectare of energy, where the biggest portion was fuel energy inputs with 45.15 per cent of the total consumed energy and the next was chemical fertilizers with 34.21 per cent (specially nitrogen filled with 31.737 per cent) (Tipi et al., 2009). Other researches also showed that energy ratios in Australian and Indian rice planting systems were similar (Iqbal, 2007; Khan et al., 2010). In another research, the highest amount of fuel consumption and energy input was land preparation operation (Canakci et al., 2005). On the other hand, researches showed that fuel comprises the biggest portion of energy input compared to other direct inputs (Strapatsa et al., 2006). Fuel consumption per unit of field area is affected by factors such as tractor's steam horsepower, depth of plowing, soil type, etc (Kaltsas et al., 2007). Therefore, by analyzing energy input in growing wheat, we realize the use of all energy forms.

The comparison between energy input and global warming potential resulting from them showed that there was a significant relationship between the two. In this regard, Wood and Cowie (2004) stated that CO_2 emission during various agricultural activities either happened directly through consuming fossil fuel or indirectly at the time of production or transportation of the field's needed inputs (herbicides, pesticides and chemical fertilizers). Pathak and Vassmann (2007) stated that agricultural and non-

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

agricultural operations (production and transportation of fertilizers and pesticides) in production of rice, made 80-90 and 16-91 kg eq-CO_2 ha^{-1} in global warming potential, respectively. Furthermore, the results of similar researches in olive and sugar beet have shown that consumption of chemical fertilizers, especially nitrogen fertilizer and fossil fuel has had the biggest effect in GHG emission and global warming potential (Kaltsas et al., 2007; Tzilivakis et al., 2005a). In this respect, Soltani et al. (2013) stated that the highest and lowest global warming potentials in the unit of weight were 271.5 and 103.8 kg eq-CO_2 t^{-1}, respectively, and the unit of energy input were 44.6 and 34.8 kg eq-CO_2 GJ^{-1} and in the unit of energy output were 11.7 and 4.5 kg eq-CO_2 GJ^{-1}. In the other research results showed average reduction levels of up to 20% and 25% per material input for spring and summer systems, leading to impact reductions which ranged from 8% to 11% for spring farms and 19% to 25% for summer farms depending on the chosen impact category (Mohammadi et al., 2014). The energy use efficiency was improved about 25% by converting present farms to target units. Furthermore, the GHG emission of each input was investigated for present and optimum units. The results indicated that the total GHG emission of present and optimum farms was calculated as 1847.26 and 1483.52 kgCO_2eq. ha^{-1}, respectively. Moreover, the effect of energy optimization in reduction of GHG emission was found to be as 363.74 kgCO_2eq. ha^{-1} (Nabavi Pelesaraei et al., 2014). Kaltas et al. (2007) investigated the two planting methods organic and conventional in Greece and decided that global warming potential was less in the organic method than in the conventional method. Dayer and Desjardins (2003) investigated the effective management of farm machinery in GHG emission in Canada's agriculture. They showed that decrease in consumption of fossil fuel reduced GHG emission. The issue of using fossil fuel energy in agriculture is very important because of the preservation of natural resources and also because of the release of greenhouse gases into the atmosphere. Furthermore, developing agricultural systems with the least energy input can help reduce GHG emission in agriculture.

REFERENCES

[1] Akcaoz, H., Ozcatalbas, O., Kizilay, H. (2009): Analysis of energy use for pomegranate production in Turkey. Journal of Food, Agriculture, and Environment 7: 475-80.

[2] Beheshti Tabar, I., Keyhani, A., Rafiee, R. (2010): Energy balance in Iran's Agronomy. Renewable and Sustainable Energy Reviews 14: 849-855.

[3] Canakci, M., Topakci, M., Akinci, I., Ozmerzi, A. (2005): Energy use pattern of some field crops and vegetable production: case study for Antalya region, Turkey. Energy Conversion and Management 46: 655-666.

[4] Chauhan, S., Mohapatra, P. K. J., Pandey, K. P. (2006): Improving energy productivity in paddy production through benchmarking: an application of data envelopment analysis. Energy Conversion and Management 47: 1063-1085.

[5] Dalgaard, T., Halberg, N., Porter, J. R. (2001): A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. Agriculture, Ecosystems and Environment 87: 51-65.

[6] Dayer, J. A., Desjardins, D. L. (2003): The impact of farm machinery management on the greenhouse gas emissions from Canadian agriculture. Journal of Sustainable Agriculture 22: 59-74.

[7] Ghorbani, R., Mondani, F., Amirmoradi, S., Feizi, H., Khorramdel, S., Teimouri, M., Sanjani, S., Anvarkhah, S., Aghel, H. (2011): A case study of energy use and economical analysis of irrigated and dryland wheat production systems. Applied Energy 88: 283-288.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

[8] Green, M. (1987): Energy in pesticide manufacture, distribution and use. - In: Helsel, Z.R. (Ed.) Energy in Plant Nutrition and Pest Control. Elsevier, Amsterdam, ISBN 0-444-42753-8, 7: 165-177.
[9] Hatirli, S. A., Ozkan, B., Fert, C. (2006): Energy inputs and crop yield relationship in greenhouse tomato production. Renewable Energy Journal 31: 427-438.
[10] IPCC. (2007a): Intergovernmental Panel on Climate Change (IPCC). Climate change group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.
[11] IPCC. (2007b): Intergovernmental Panel on Climate Change (IPCC). Climate change 2007: the physical science basis. Contribution of working group I to the assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.
[12] IPCC. (2007c): Intergovernmental Panel on Climate Change (IPCC). Climate change. Impacts, adaptation and vulnerability. In: Parry, M. L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson, editors. Contribution of Working Group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press, 976 p.
[13] IPCC. (2007d): Intergovernmental Panel on Climate Change (IPCC). Climate change group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.
[14] Iqbal, T. (2007): Energy input and output for production of Boron rice in Bangladesh. Electronic Journal of Environmental, Agricultural and Food Chemistry 7: 2717-2722.
[15] Jarvis, P. (2000): Ecological principles and environmental Issues. Pearson Education Limited Publication. London.
[16] Johnson, J. M. F., Franzluebbers, A. J., Weyers, S. L., Reicosky, D. C. (2007): Agricultural opportunities to mitigate greenhouse gas emissions. Environment Pollution 50: 107-124.
[17] Kaltsas, A. M., Mamolos, A. P., Tsatsarelis, C. A., Nanos, G. D., Kalburtji, K. L. (2007): Energy budget in organic and conventional olive groves. Agriculture, Ecosystems and Environment, 122(2): 243-251.
[18] Khan, S., Khan, M. A., Latif, N. (2010): Energy requirement and economic analysis of wheat, rice and barley production in Australia. Soil and Environment 29(1): 61-68.
[19] Kizilaslan, N. (2009): Energy use and input-output energy analysis for apple production in Turkey. Journal of Food, Agricultural and Environment 7: 419-423.
[20] Koga, N. (2008): An energy balance under a conventional crop rotation system in northern Japan: Perspectives on fuel ethanol production from sugar beet. Agriculture, Ecosystems and Environment 125: 101-110.
[21] Koocheki, A. L., Ghorbani, R., Mondani, F., Alizadeh, Y., Moradi, M. (2011): Pulses Production Systems in Term of Energy Use Efficiency and Economical Analysis in Iran. International Journal of Energy Economics and Policy 1(4): 95-106.
[22] Mandal, K. G., Saha, K. P., Ghosh, P. K., Hati, K. M., Bandyopadhyay, K. K. (2002): Bio-energy and economic analysis of soybean based crop production systems in Central India. Biomass and Bioenergy 23(5): 337-345.
[23] Mirin, A., Senhaji, F., Pimental, D. (2001): Energy analysis of sugarcane production in Morocco. Environment, Development and Sustainability 3: 109-126.
[24] Mohammadi, A., Rafiee, S., Jafari, A., Keyhani, A., Dalgaard, T., Knudsen, M., Nguyen T., Borek, R., Hermansen, J. (2014): Joint life cycle assessment and data envelopment analysis for the benchmarking of environmental impact in rice paddy production. Journal of Cleaner Production 8: 1-12.
[25] Moore, S. R. (2010): Energy efficiency in small-scale bio intensive organic onion production in Pennsylvania, USA. Renewable Agriculture and Food System 25: 181-188.
[26] Nabavi Pelesaraei, A., Abdi, R., Rafiee, S., Taromi, K. (2014): Applying data envelopment analysis approach to improve energy efficiency and reduce greenhouse gas

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161

emission of rice production. Engineering in Agriculture, Environment and Food 7: 155-162.

[27] Nassi, O., Di Nasso, N., Bosco, B., Di Bene, C., Coli, A., Mazzoncini, M., Bonari, E. (2011): Energy efficiency in long-term Mediterranean cropping systems with different management intensities. Energy 36: 1924-1930.

[28] Ozkan, B., Akcaoz, H., Fert, C. (2004): Energy input-output analysis in Turkish agriculture. Renewable Energy 29: 39-51.

[29] Pathak, H., Wassmann, R. (2007): Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. Agricultural Systems 94: 807-825.

[30] Pervanchon, F., Bockstaller, C., Girardin, P. (2002): Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. Agricultural Systems 72: 149-172.

[31] Rathke, G. W., Diepenbrock, W. (2006): Energy balance of winter oilseed rape cropping as related to nitrogen supply and preceding crop. European Journal of Agronomy 24: 35-44.

[32] Robertson, G. P., Paul, E. A., Harwood, R. R. (2000): Greenhouse gases in intensive agriculture: contributions of individual gases to the radiative forcing of the atmosphere. Science 289: 1922-1925.

[33] Singh, H., Singh, A. K., Kushwaha, H. L., Singh, A. (2007): Energy consumption pattern of wheat production in India. Energy 32: 1848-1854.

[34] Singh, H., Mishra, D., Nahar, N. M., Ranjan, M. (2003): Energy use pattern in production agriculture of typical village in arid zone, India part-II. Energy Conversation Management 43: 1053-1067.

[35] Soltani, A., Rajabi, M. H., Zeinali, E., Soltani, E. (2013): Energy inputs and greenhouse gases emissions in wheat production in Gorgan, Iran. Energy 50: 54-61.

[36] Strapatsa, A. V., Nanos, G. D., Tsatsarelis, C. A. (2006): Energy flow for integrated apple production in Greece. Agriculture, Ecosystems and Environment 116: 176-180.

[37] Tabatabaeefar, A., Emamzadeh, H., Ghasemi Varnamkhasti, M., Rahimizadeh, R., Karimi, M. (2009): Comparison of energy of tillage systems in wheat production. Energy 34: 41-45.

[38] Tipi, T., Cetin, B., Vardar, A. (2009): An analysis of energy use and input costs for wheat production in Turkey. Journal of Agriculture and Environment 7: 352-356.

[39] Tzilivakis, J., Warner, D. J., May M., Lewis, K. A., Jaggard K. (2005a): An assessment of the energy inputs and greenhouse gas emission in sugar beet (Beta vulgaris L.) production in the UK. Agricultural Systems 85: 101-119.

[40] Tzilivakis, J., Jaggard, K., Lewis, K. A., May, M., Warner, D. J. (2005b): Environmental impact and economic assessment for UK sugar beet production systems. Agriculture, Ecosystems & Environment 107: 341-358.

[41] Uphoff, N. (2012): Supporting food security in the 21st century through resource-conserving increase in agricultural production. Agriculture and Food Security 1: 18-30.

[42] Wood, S., Cowie, A. (2004): A review of greenhouse gas emission factors for fertilizer production. Research and Development Division, State Forests of New South Wales. Cooperative Research Center for Greenhouse Accounting.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1504_143161