American-Eurasian J. Agric. & Environ. Sci., 3 (4): 604-608, 2008
ISSN 1818-6769

Effect of Farm Size on Energy Ratio for Wheat Production: A Case Study from Ardabil Province of Iran

S. Shahin, A. Jafari, H. Mobli, S. Rafiee and M. Karimi

Department of Agricultural Machinery, Faculty of Biosystems Engineering, Tehran University, Karaj, Iran

Abstract: The aim of this study was to examine direct and indirect input energy in per hectare in wheat production. The research also sought to analyse the effect of farm size. For this purpose, the data were collected from 300 wheat farmers by questionnaire method. The results indicated that wheat production consumed a total of 38.36 GJ ha^{-1} of which fertilizer energy consumption was 38.45% followed by diesel and machinery energy. Output–input energy ratio and energy productivity were found to be 3.13 and 0.16 kg of wheat MJ^{-1}, respectively. Large farms were more successful in energy use and energy ratio. It was concluded that energy use management at farm level could be improved to give more efficient and use of energy.

Key words: Energy requirements · Wheat production · Energy productivity · Energy ratio

INTRODUCTION

Wheat (*Triticum aestivum* L.) is among the oldest and most extensively grown of all crops. It is a main cereal cultivated throughout the world along with rice, barley, maize, rye, sorghum, oats and millet. Nowadays, wheat cultivars have been developed for different qualities in accordance with the development of genetic recombination [1]. Wheat is grown under irrigated as well as rain-fed conditions worldwide. Under rain-fed conditions the developing grains are frequently exposed to mild to severe stress at different stages of grain development [2]. Based on Ministry of Jihad-e-Agriculture of Iran statistics, Iran produced about 14307969 tones of wheat in 2005 [3]. Wheat is the single most important agricultural commodity in Ardabil province. In 2005, for example, total crops were planted in 664922 ha, more than 54% of which was planted by wheat. Wheat is grown throughout Ardabil, Iran under boat dry land and irrigated conditions.

The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy [4]. Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices, or both [5]. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution Reduction [6]. Application of integrated production methods are recently considered as a means to reduce production costs, to efficiently use human labor and other inputs and to protect the environment (often in conjunction with high numbers of tourists present in the area). Energy budgets for agricultural production can be used as building blocks for life-cycle assessments that include agricultural products and can also serve as a first step towards identifying crop production processes that benefit most from increased efficiency [7]. Many researchers have studied energy and economic analysis to determine the energy efficiency of plant production, such as sugarcane in Morocco [8], wheat, maize, sugar beet, sunflower, grape, olive, almond, barley, oat, rye, orange, lemon, apple, pear, peach, apricot and plum in Italy [9], rice in Malaysia [10], sweet cherry, citrus, apricot, tomato, cotton, sugar beet, greenhouse vegetable, some field crops and vegetable in turkey [11,12], soybean, maize and wheat in Italy [13], soybean based production system, potato in India [14,15], wheat, maize, sorghum in United States [16], cotton, sunflower in Greece [17] oilseed rape in Germany [18].

The aim of the present paper is to study the energy input and output per hectare for the production of wheat based on farm size in Ardabil, Iran. It also identifies

Corresponding Author: Dr. M. Karimi, Department of Agricultural Machinery, Faculty of Biosystems Engineering, Tehran University, Karaj, Iran

operations where energy savings could be realized by changing applied practices in order to increase the energy ratio and propose improvements to reduce energy consumption for wheat production.

MATERIALS AND METHODS

The study was carried out in 300 wheat producer in Ardabil, Iran. Thirty villages were chosen to represent the whole study area. The province is located in the northwest of Iran, within 34° 04' and 39° 42' north latitude and 47° 02' and 48° 55' east longitude. The total area of the Ardabil province is 1,795,200 ha and the farming area is 718,614 ha, with a share of 40.03%. Data were collected from the growers by using a face-to-face questionnaire performed in November–December 2006. The data collected belonged to the production period of 2005–2006. The secondary material used in this study was collected from the previous studies and publications by some institutions like FAO.

Farms were randomly chosen from the villages in the area of study. The size of each sample was determined using Eq. (1) derived from Neyman technique [19].

$$n = \frac{(\sum N_h S_h)}{N^2 D^2 + \sum N_h S_2^h} \qquad (1)$$

where n is the required sample size; N is the number of holdings in target population; Nh is the number of the population in the h stratification; Sh is the standard deviation in the h stratification, S2h is the variance of h stratification; d is the precision (x - X); z is the reliability coefficient (1.96 which represents the 95% reliability); D2 =d2/ z2.

The permissible error in the sample size was defined to be 5% for 95% confidence and sample size was calculated as 300 farms. For the growth and development, energy demand in agriculture can be divided into direct and indirect, renewable and non-renewable energies [4]. The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel oil, fertilizer, pesticides and seed amounts and output yield values of wheat crops have been used to estimate the energy ratio. Energy equivalents shown in Table 1 were used for estimation. The sources of mechanical energy used on the selected farms included tractors and diesel oil.

The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations.

Table 1: Energy equivalent of inputs and outputs in agricultural production

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Reference
A. Inputs			
1. Human labor	h	1.96	[20,21,22]
2. Machinery	h	62.70	[22,23, 24]
3. Diesel fuel	L	56.31	[22,23, 24]
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		66.14	[21,25]
(b) Phosphate (P_2O5)		12.44	[21,25]
(c) Potassium (K_2O)		11.15	[21,25]
(d) Zinc (Zn)		8.40	[26,27]
5. Farmyard manure	kg	0.30	[11,20,22,28]
6. Chemicals	kg	120.00	[12,14,24]
7. Water for irrigation	m^3	1.02	[29,30]
9. Seed (wheat)	kg	14.70	[20,28]
B. Outputs			
1. Grain wheat	kg	14.7	[20,28]
2. Straw	kg	12.50	[20,28]

Therefore, the energy consumed was calculated using conversion factors (1L diesel = 56.31 MJ) and expressed in MJ ha^{-1} [17].

Basic information on energy inputs and wheat yields were entered into Excel spreadsheets, SPSS 15 spreadsheets. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity and the specific energy were calculated [11, 13].

$$\text{Energy use efficiency} = \text{Energy Output (MJ ha}^{-1}\text{)} / \text{Energy Input (MJ ha}^{-1}\text{)} \qquad (2)$$

$$\text{Energy productivity} = \text{Grain output (kg ha}^{-1}\text{)} / \text{Energy Input (MJ ha}^{-1}\text{)} \qquad (3)$$

$$\text{Specific energy} = \text{Energy input (MJ ha}^{-1}\text{)} / \text{Grain output (kg ha}^{-1}\text{)} \qquad (4)$$

$$\text{Net energy} = \text{Energy Output (MJ ha}^{-1}\text{)} - \text{Energy Input (MJ ha}^{-1}\text{)} \qquad (5)$$

Indirect energy included energy embodied in seeds, fertilizers, manure, chemicals, machinery while direct energy covered human labor and diesel used in the wheat production. Nonrenewable energy includes diesel, chemical, fertilizers and machinery and renewable energy consists of human labor, seeds, manure.

RESULTS AND DISCUSSION

Average farm size was 6.4 ha and wheat production occupied 51.4% of total farm lands. The other vegetables

Table 2: Input and output for wheat production

	Farm size groups (ha)			
	0.1-2.0	2.1-5.0	5.1+	
A-Inputs				
1-Labor (h ha ha^{-1})	161.85	153.75	126.24	147.28
Land preparation	15.020	14.26	11.71	13.66
Seeding	10.71	10.17	8.35	9.74
Irrigation	51.37	48.80	40.06	46.74
Fertilizer application	18.42	17.49	14.37	16.76
Spraying	6.23	5.92	4.86	5.67
Harvesting	31.97	30.37	24.94	29.09
transporting	28.13	26.72	21.94	25.59
2-Machinery (h ha ha^{-1})	72.97	69.32	56.91	66.40
Land preparation	12.74	12.10	9.93	11.59
Seedling	9.42	8.95	7.34	8.57
Irrigation	28.00	26.61	21.84	25.48
Fertilizer application	2.48	2.36	1.93	2.26
Spraying	1.57	1.49	1.22	1.43
Harvesting	6.39	6.07	4.98	5.81
transporting	12.37	11.75	9.64	11.25
3-Diesel (L ha ha^{-1})	217.85	206.95	169.90	198.23
Land preparation	87.39	83.02	68.16	79.52
Seedling	7.04	6.68	5.49	6.40
Irrigation	65.44	62.17	51.04	59.55
Fertilizer application	7.71	7.32	6.01	7.01
Spraying	6.34	6.02	4.94	5.77
Harvesting	18.75	17.82	14.62	17.06
transporting	25.18	23.92	19.64	22.91
4-Fertilizers (kg ha ha^{-1})	340.00	325.99	391.65	352.61
Nitrogen (N)	198.32	182.23	201.78	194.11
Phosphorus (P2O5)	100.02	102.1	148.21	116.84
Potassium (K2O)	39.43	39.43	39.43	39.43
Zinc (Zn)	2.23	2.23	2.23	2.23
5-Manure (kg ha ha^{-1})	4444.00	4869.00	6954.00	5423.00
6-Chemicals (kg ha ha^{-1})	2.00	2.00	2.00	2.00
7-Water (m3 ha ha^{-1})	4147.20	4147.20	4147.20	4147.20
8-Seeds (kg ha ha^{-1})	250.00	250.00	250.00	250.00
B-Outputs				
1-wheat grain (kg ha ha^{-1})	5777.00	6234.00	7061.00	6357.00
2-Straw (kg ha ha^{-1})	1842.00	2015.00	2541.00	2132.00

Table 3: Energy consumption and output for wheat production (MJ ha^{-1})

	Farm size groups (ha)			Weighted average	
	0.1-2.0	2.1-5.0	5.1+	Quantity	(%)
Inputs					
1-Labor (h ha^{-1})	317.226	301.35	247.43	288.66	0.75
Land preparation	29.44	27.95	22.95	26.78	0.07
Seeding	20.99	19.93	16.36	19.10	0.05
Irrigation	100.68	95.65	78.52	91.61	0.24
Fertilizer application	36.10	34.28	28.16	32.85	0.09
Spraying	12.21	11.60	9.52	11.11	0.03
Harvesting	62.66	59.52	48.88	57.02	0.15
transporting	55.13	52.37	43.00	50.17	0.13
2-Machinery (h ha^{-1})	4575.22	4346.36	3568.26	4163.28	10.85
Land preparation	798.79	758.67	622.61	726.69	1.89
Seedling	590.63	561.16	460.22	537.34	1.40
Irrigation	1755.60	1668.45	1369.37	1597.80	4.17
Fertilizer application	155.49	147.97	121.01	141.49	0.37
Spraying	98.44	93.42	76.49	89.45	0.23
Harvesting	400.65	380.59	312.25	364.49	0.95
transporting	775.60	736.73	604.43	705.58	1.84
3-Diesel (L ha^{-1})	12267.10	11653.35	9567.06	11162.52	29.10
Land preparation	4920.93	4674.85	3838.08	4477.95	11.67
Seedling	396.42	376.15	309.14	360.57	0.94
Irrigation	3684.93	3500.79	2874.06	3353.26	8.74
Fertilizer application	434.15	412.19	338.42	394.92	1.03
Spraying	357.00	338.99	278.17	324.72	0.85
Harvesting	1055.81	1003.44	823.25	360.83	2.51
transporting	1417.89	1346.93	1105.92	1290.25	3.36
4-Fertilizers (kg ha^{-1})	14819.50	13781.19	15647.83	14749.51	38.45
Nitrogen (N)	13116.90	12052.69	13345.73	12838.43	33.47
Phosphorus (P_2O5)	1244.25	1270.12	1843.73	1452.70	3.79
Potassium (K_2O)	439.65	439.64	439.64	439.64	1.15
Zinc (Zn)	18.73	18.73	18.73	18.73	0.05
5-Manure (kg ha^{-1})	1333.20	1460.70	2086.20	1626.70	4.24
6-Chemicals (kg ha^{-1})	202.40	202.40	202.40	202.40	0.53
7-Water (m^3 ha^{-1})	2488.32	2488.32	2488.32	2488.32	6.49
8-Seeds (kg ha^{-1})	3675.00	3675.00	3675.00	3675.00	9.58
Total energy input	39677.99	37908.68	37482.51	38356.39	100.00
Total energy output	107946.90	116827.30	135559.20	120097.90	_
Energy ratio	2.72	3.08	3.62	3.13	_
Energy productivity (kg seed MJ^{-1})	0.14	0.16	0.19	0.16	_

grown besides wheat were potato, sugar beet, barley. 100% of total land in each farm was irrigated; Land in the selected farms was owned (100%).

The input used in wheat production and their energy equivalents, output energy equivalent and energy ratio are illustrated in Table 2 and Table 3, respectively.

Table 2 shows that average labour used in wheat production was 147.28 h ha^{-1}. In the study region, fertilizer was typically applied two times as a basal dressing and one top dressing to give an average of 194.11 kg ha^{-1} chemicals as total plant nutrients.

The shares of nitrogen, phosphorus and potassium fertilizer were 55.1%, 32.9% and 11.2%, respectively, in the total chemical fertilizer used. One the other hand, the use of human power and machinery were 147.28 and 66.40 h ha^{-1}, respectively.

Based on the energy equivalents of the input and output given in Table 1, the average total energy consumed per farm per year was determined as 38.36 GJ ha^{-1} (Table 3). Energy use per hectare was 5.8% higher on small farms decreasing when the farm size group increased.

Table 4: Total energy input in the form of direct, indirect, renewable and non-renewable for wheat production (MJ ha^{-1})

	Farm size groups (ha)			
	0.1-2.0	2.1-5.0	5.1+	
Direct energy[a]	15072.68	14443.02	12302.82	13939.51
Indirect energy[b]	24605.32	23465.65	25179.69	24416.89
Renewable energy[c]	3992.23	3976.35	3922.43	3963.66
Non-renewable energy[d]	35685.77	33932.33	33560.08	34392.73
Total energy input	39677.99	37908.68	37482.51	38356.39

[a]Includes human labor, diesel.

[b]Includes seeds, fertilizers, manure, chemicals, machinery.

[c]Includes human labor, seeds, manure.

[d]Includes diesel, chemical, fertilizers, machinery.

With respect to machinery and diesel consumption, our results showed that tractor use averaged 66.4 h per hectare of which 72.8% was devoted to Irrigation, land preparation and transporting. Fertilizer energy was 38.45% of the total input energy consumed in wheat production followed by diesel (29.10%) and machinery (10.85%).

Energy equivalent of human labor input was 288.7 MJ ha^{-1} or 0.75% of the total energy use. Labor used for Land preparation, Seeding, irrigation, Fertilizer application, spraying, Harvesting and transporting practice decreased as farm size increased.

Fertilizer energy (14.75 GJ ha^{-1}) was 38.45% of the total input energy, nitrogen accounting for 87.04% of total fertilizer, phosphorus 9.85% and potassium 2.98%. According to the result findings fertilizer and nitrogen use were highest on the large farms, whereas nitrogen was used least on the medium farms.

An average of 202.40MJ ha^{-1} pesticide energy was used; meaning 0.53% of the total energy consumption. The diesel energy consumption was 11.16 GJ ha^{-1} and machinery energy consumption was 4.16 GJ ha^{-1}. According to the research results machinery energy use in small farms was higher. The energy to pump the water (2.49 GJ ha^{-1}) constituted 6.49% of the total input energy.

An average of the output–input ratio was determined at 3.13 and increased as the farm size increased. According to the research results (Table 3), energy was used more efficiently in large farms and gave parallel results for energy productivity ranging from 0.14 kg wheat MJ^{-1} to 0.19 kg MJ^{-1} on large farms.

With respect to the improving of energy efficiency, the diesel, fertilizer and machinery management seemed to be the most significant three categories.

On the other hand, the share of direct input energy was 36.3% in the total energy compared to 63.7% for the indirect energy (Table 4). The research results shown that on average the non-renewable form of energy input was 89.7% compared to 10.3% for renewable energy.

CONCLUSION

The data used in this research for the wheat production were collected from 300 farms located in the Ardabil province of Iran.

Wheat production consumed a total of 38.36 GJ ha^{-1} energy which is mainly on fossil fuels. Fertilizer energy was the biggest energy input followed by diesel and machinery. Land preparation, planting and cultivating were the main input items for machinery requirements and costs.

Better energy efficiency and productivity were found on the large farms. According to these criteria large farms were more successful in energy use.

Energy management is an important issue in terms of efficient, sustainable and economic use of energy. For this reason, it is seen that the importance given to efficient use of energy, sustainability and economy has increased in many countries and Iran.

Reducing inputs would provide more efficient input use of mainly machinery, fertilizer and pesticides. Application of integrated pest management techniques would improve pesticide use. In addition to these applications choosing the appropriate cropping systems would be useful not only for reducing negative effects to environment, human health, maintaining, sustainability and decreasing production costs, but also for providing higher energy use efficiency.

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