Energy use and economical analysis of wheat production in Iran: A case study from Ardabil province

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Results indicated that total energy inputs were 47.08 $GJha^{-1}$. About 31.19% was generated by chemical fertilizers, 26.05% from diesel oil and machinery. About 73.27% of the total energy inputs used in wheat production was indirect (seeds, fertilizers, manure, chemicals, machinery) and 26.73% was direct (human labor, diesel). Mean grain wheat yield was about 4514.8 $kgha^{-1}$, it obtained under normal conditions on irrigated farming, and taking into account the energy value of the seed, the net energy and energy productivity value was estimated to be 45.71 $GJha^{-1}$ and 0.096 kg MJ^{-1}, respectively. The ratio of energy outputs to energy inputs was found to be 1.97. This indicated an intensive use of inputs in wheat production not accompanied by increase in the final product. Cost analysis revealed that total cost of production for one hectare of wheat production was 809.44 $. Benefit–cost ratio was calculated as 1.43.

Key words: energy ratio, economical analysis, wheat, Iran

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 (Hung *et al*., 2008). 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 (Singh *et al*., 2008). Based on Ministry of Jihad-e-Agriculture of Iran (Anonymous, 2005) statistics, Iran, produced about 14307969 tones of wheat in 2005. 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.

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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 (Alam *et al*., 2005). 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 (Esengun *et al*., 2007). 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 (Uhlin, 1998). 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 (Piringer and Steinberg, 2006). Many researchers have studied energy and economic analysis to determine the energy efficiency of plant production, such as sugarcane in Morocco (Mrini *et al*., 2001), wheat, maize, sugar beet, sunflower, grape, olive, almond, barley, oat, rye, orange, lemon, apple, pear, peach, apricot and plum in Italy (Triolo *et al*., 1987), rice in Malaysia (Bockari-Gevao *et al*., 2005), sweet cherry, citrus, apricot, tomato, cotton, sugar beet, greenhouse vegetable, some field crops and vegetable in turkey (Demircan *et al*., 2006; Canakci *et al*., 2005), soybean, maize and wheat in Italy (Sartori *et al*., 2005), soybean based production system, potato in India (Mandal *et al*., 2002; Yadav *et al*., 1991), wheat, maize, sorghum in United States (Franzluebbers and Francis, 1995), cotton, sunflower in Greece (Tsatsarelis, 1991; Kallivroussis *et al*., 2002), oilseed rape in Germany (Rathke and Diepenbrock, 2006).

Nomenclature

n	required sample size
N	number of holdings in target population
N_h	number of the population in the h stratification
S^2_h	variance of h stratification
d	precision ($\bar{x} - \bar{X}$)
z	reliability coefficient (1.96 in the case of 95% reliability)
D^2	d^2/z^2

The aim of this study was to determine the energy input and output used in wheat production and to evaluate a production cost analysis in Ardabil, Iran. It also identifies 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 250 wheat producers 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 collected data 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 (Yamane, 1967).

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

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 250 farms. For the growth and development, energy demand in agriculture can be divided into direct and indirect, renewable, and non-renewable energies (Alam *et al*., 2005). 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. Therefore, the energy consumed was calculated using conversion factors (1L diesel = 56.31 MJ) and expressed in MJ ha^{-1} (Tsatsarelis, 1991). 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 (Demircan *et al*., 2006; Sartori *et al*., 2005).

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

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

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

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

Indirect energy included energy embodied in seeds, fertilizers, manure, chemicals, machinery while direct energy covered human labor and diesel were used in the wheat production. Nonrenewable energy includes diesel, chemical, fertilizers and machinery, and renewable energy consists of human labor, seeds, manure were considered. In the last part of the research, a production cost analysis of wheat production was investigated, and net profit and benefit–cost ratio was calculated. The net return was calculated by subtracting the total cost of production from the gross value of production per hectare. The benefit–cost ratio was calculated by dividing the gross value of production by the total cost of production per hectare (Demircan *et al*., 2006; Ozkan *et al*., 2004).

Results and Discussion

Socio-economic structures of farms

Average farm size was 6.4 ha and wheat production occupied 51.4% of total farm lands. The other vegetables 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 agronomic practices during the growing process of wheat along with the periods relevant to these preparations were shown in Table 2. Land preparation and soil tillage were mostly accomplished by a Massey Ferguson 28575 hp tractor along with using moldboard plow, disc harrows and land leveller. All practices applied for wheat production in the area studied were listed in Table 2.

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

Particulars	**Unit**	**Energy equivalent (MJ unit^{-1})**	**References**
A. Inputs			
1. Human labor	h	1.96	(Ozkan *et al*., 2004; Yilmaz *et al*., 2005; Singh *et al*., 2002)
2. Machinery	h	62.7	(Erdal *et al*., 2007; Singh *et al*., 2002; Singh, 2002)
3. Diesel fuel	L	56.31	(Erdal *et al*., 2007; Singh *et al*., 2002, Singh, 2002)
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		66.14	(Esengun *et al*., 2007; Yilmaz *et al*., 2005)
(b) Phosphate (P_2O5)		12.44	(Esengun *et al*., 2007; Yilmaz *et al*., 2005)
(c) Potassium (K_2O)		11.15	(Esengun *et al*., 2007; Yilmaz *et al*., 2005)
(d) Zinc (Zn)		8.40	(Pimentel, 1980; Argiro *et al*., 2006)
5. Farmyard manure	kg	0.30	(Demircan *et al*., 2006; Ozkan *et al*., 2004; Singh *et al*., 2002)
6. Chemicals	kg	120	(Canakci *et al*., 2005; Mandal *et al*., 2002; Singh, 2002)
7. Water for irrigation	m^3	1.02	(Acaroglu, 1998; Acaroglu and Aksoy, 2005)
9. Seed (wheat)	kg	14.7	(Ozkan *et al*., 2004)
B. Outputs			
1. Grain wheat	kg	14.7	(Ozkan *et al*., 2004)
2. Straw	kg	12.5	(Ozkan *et al*., 2004)

The inputs and output were used in wheat production in the area of survey can be seen in Table 3. Their energy equivalents with output energy rates and their equivalents are illustrated in Table 4. The results revealed that 161.85 h of human power and 72.98 h of machine power was required per hectare of wheat production in the research area. The amount of fertilizers used for wheat growing was 326.12 kg ha^{-1}. All chemical fertilizers, nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) and Zinc (Zn) were 60.85%, 26.37%, 12.10% and 0.68%, respectively.

Table 2. Management practices for the wheat.

Practices/operations	Wheat
Names of varieties	Roshan-Amir
Land preparation tractor used: 285 MF 75 hp	Moldboard plow, Disc harrows, Land leveller
Land preparation period	Sep – Oct
Average tilling number	2.5
Planting period	Oct
Fertilization period	Nov – Apr
Average number of fertilization	3
Irrigation period	Nov – Mar – Apr – May
Average number of irrigation	4
Spraying period	Apr – May
Average number of spraying	2
Harvesting period	July
Average number of harvesting	1

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Analysis of input–output energy use in wheat production

Total energy used in various farm operations during wheat production was 47078.50 $MJha^{-1}$. Chemical fertilizer consumes 31.19% of total energy inputs followed by diesel energy 26.05% during production period. Diesel energy was mainly consumed for land preparation, cultural practices and transportation. Average annual grain yield of farms investigated was 4514.80 kg ha^{-1} and calculated total energy output was 92785.56 MJ ha^{-1}. It is showed that chemicals was the least demanding energy input for wheat production with 260.40 MJ ha^{-1} (only 0.55% of the total sequestered energy), followed by human labor by 317.226 MJ ha^{-1}(0.67%) as shown in Table 4. As comparison to India, Singh *et al*. (2007) reported that yield, total energy input and output, in wheat farming were 2550.5kg ha^{-1}, 15572.2 and 63846.02 MJ ha^{-1}, respectively. In another study in Europe, Kuesters and Lammel (1999) found that total energy input in wheat production were between 7.5 and 17.5 GJ ha^{-1}. In Turkey, Canakci *et al*. (2005) noted that the rates of other inputs in the total amount of energy such as fertilizers application, seeds, Diesel, chemicals, manpower and other inputs in wheat production were 54.1%, 25.2%,17.4%, 0.6%, 0.1% and 2.6%, respectively.

Table 3. Amounts of inputs and wheat in wheat production.

	Quantity per unit area(ha)
A-Inputs	
1-Labor (h ha^{-1})	161.85
Land preparation	15.02
Seeding	10.71
Irrigation	51.37
Fertilizer application	18.42
Spraying	6.23
Harvesting	31.97
transporting	28.13
2-Machinery (h ha^{-1})	72.97
Land preparation	12.74
Seedling	9.42
Irrigation	28.00
Fertilizer application	2.48
Spraying	1.57
Harvesting	6.39
transporting	12.37
3-Diesel (L ha^{-1})	217.85
Land preparation	87.39
Seedling	7.04
Irrigation	65.44
Fertilizer application	7.71
Spraying	6.34
Harvesting	18.75
transporting	25.18
4-Fertilizers (kg ha^{-1})	326.12
Nitrogen (N)	198.44
Phosphorus (P_2O5)	86.02
Potassium (K_2O)	39.43
Zinc (Zn)	2.23
5-Manure (kg ha^{-1})	15245.46
6-Chemicals (kg ha^{-1})	2.17
7-Water (m^3 ha^{-1})	4147.20
8-Seeds (kg ha^{-1})	248.4
B-Outputs	
1-wheat grain (kg ha^{-1})	4514.80
2-Straw (kg ha^{-1})	2113.44

The energy input and output, yield, energy use efficiency, specific energy, energy productivity and net energy of wheat production in the Ardebil province are shown in Table 5. Energy use efficiency (energy ratio) was calculated as 1.97. In Turkey, Canakci *et al*. (2005) reported wheat output/input ratio as 2.8. Singh *et al*. (2007), calculated energy output/input ratio 2.9, 4.0, 4.2 and 5.2 at different locations in India. In this study, the average energy productivity of farms was 0.096. This means that 0.096 grain output was obtained per unit energy. Calculation of energy productivity rate is well documented in the literatures such as stake-tomato (1.0) (Esengun *et al*., 2007), cotton (0.06) (Yilmaz *et al*., 2005), sugar beet (1.53) (Erdal *et al*., 2007).

The specific energy and net energy of wheat production were 10.43 MJ kg^{-1} and 45707.06 MJ ha^{-1}, respectively. Canakci *et al*. (2005) reported specific energy for field crops and vegetable production in Turkey, as 5.24 for wheat, 11.24 for cotton, 3.88 for maize, 16.21 for sesame, 1.14 for tomato, 0.98 for melon and 0.97 for water- melon.

Table 4. Amounts of inputs and output in wheat production.

Quantity (inputs and outputs)	**Quantity per unit area (ha)**	**Total energy equivalent (MJ ha^{-1})**	**Percentage of the total energy input (%)**
A. Inputs			
1. Human labor (h)	161.85	317.23	0.67
2. Machinery (h)	72.97	4574.21	9.71
3. Diesel fuel (L)	217.85	12267.13	26.05
4. Chemical fertilizers (kg)	326.12		31.19
(a) Nitrogen (N)	198.44	13124.82	27.87
(b) Phosphate (P_2O_5)	86.02	1070.48	2.27
(c) Potassium (K_2O)	39.43	439.64	0.93
(d) Zinc (Zn)	2.23	18.73	0.03
5. Farmyard manure (kg)	15245.46	4574.68	9.71
6. Chemicals (kg)	2.17	260.40	0.55
7. Water for irrigation (m^3)	4247.20	4230.14	8.95
8. Seeds (wheat) (kg)	248.04	6201.05	13.17
Total energy input (MJ)		47078.50	100
B. Outputs			
1. Grain (kg)	4514.80	66367.56	71.53
2. Straw (kg)	2113.44	26418.00	28.47
Total energy output (MJ)		92785.56	100

Table 5. Energy input–output ratio in wheat production**.**

Items	Unit	production
Energy input	MJ ha^{-1}	47078.50
Energy output (grain and straw)	MJ ha^{-1}	92785.56
Grain yield	kg ha^{-1}	4514.80
Energy use efficiency	-	1.97
Specific energy	MJ kg^{-1}	10.43
Energy productivity	kg MJ^{-1}	0.096
Net energy	MJ ha^{-1}	45707.06

The distribution of total energy input as direct, indirect, renewable and non-renewable forms are shown in Table 6. The total energy input could be classified as direct energy (26.73%), indirect energy (73.27%) and renewable energy (23.56%) and non- renewable energy (76.44%).

Table 6. Total energy input in the form of direct, indirect, renewable and non-renewable for wheat production (MJ ha^{-1}).

Form of energy (MJ ha^{-1})	Wheat	%[a]
Direct energy[b]	12584.36	26.73
Indirect energy[c]	34494.14	73.27
Renewable energy[d]	11092.96	23.56
Non-renewable energy[e]	35985.54	76.44
Total energy input	47078.50	100.00

[a]Indicates percentage of total energy input.
[b]Includes human labor, diesel.
[c]Includes seeds, fertilizers, manure, chemicals, machinery.
[d]Includes human labor, seeds, manure.
[e]Includes diesel, chemical, fertilizers, machinery.

Table 7. Economic analysis of wheat.

Cost and return components	Value
Major product yield (kg ha^{-1})	4514.80
Byproduct yield (kg ha^{-1})	2113.44
Sale price of major product ($ ha^{-1})	0.24
Sale price of byproduct ($ ha^{-1})	0.037
Total gross value of production ($ ha^{-1})	1161.25
Variable cost of production ($ ha^{-1})	550.42
Fixed cost of production ($ ha^{-1})	259.02
Total cost of production ($ ha^{-1})	809.44
Gross return ($ ha^{-1})	610.83
Net return ($ ha^{-1})	351.81
Benefit to cost ratio	1.43

Economic analysis of wheat production

The total expenditure for the production was 809.44 \$ ha^{-1} while the total gross production value was found to be 1161.25 \$ ha^{-1} (Table 7). About 68% of the total expenditures were variable costs whereas 32% were fixed expenditures. The benefit–cost ratio from wheat production in the surveyed farms was calculated to be 1.43. The results were compared and consistent with finding reported by other authors, such as 2.53 for sweet cherry (Demircan *et al*., 2006), 2.37 for orange, 1.89 for lemon and 1.88 for mandarin (Ozkan *et al*., 2004), 1.03 for stake-tomato (Esengun *et al*., 2007), 0.86 for cotton (Yilmaz *et al*., 2005), 1.17 for sugar beet (Erdal *et al*., 2007).

Total energy consumption in wheat production was 47.08 GJ ha^{-1}. The energy input of chemical fertilizer was 31.19% of mainly nitrogen, the biggest share within the total energy inputs was followed by diesel fuel (26.05%). Energy use efficiency, specific energy, energy productivity and net energy were 1.97, 10.43 MJ kg^{-1}, 0.096 Kg MJ^{-1}, 45707.06 MJ ha^{-1}, respectively. About 73.27% of the total energy inputs used in wheat production was indirect, only 26.73% was direct. Approximately 76.44% of total energy input from non-renewable and 23.56% from renewable energy forms. The benefit–cost ratio was 1.43. The net return from wheat production was obtained 351.81\$ ha^{-1}. Energy management is an important issue in terms of efficient, sustainable and economic use of energy. Energy use in wheat production is not efficient and detrimental to the environment due to mainly excess input use. Therefore, reducing these inputs would provide more efficient fertilizer application and diesel. Furthermore, integrated pest control techniques should be put in practice to improve pesticide use. It can be expected that all these measurements 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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