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Energy analysis and optimization of inputs for wheat production in Marand region

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ABSTRACT

The purpose of this study is to determine energy consumption of input and output used in wheat (*Triticum aestivum* emend Fiori & Paol.)production and to optimize the energy inputs in Marand region, Iran. Data were collected from 150 farmers using a face to face questionnaire. The results revealed that wheat production consumed a total of 37694.6 MJ/ha of which fertilizers was 52.8%, followed by diesel fuel (15.3%). Output-input energy ratio and energy productivity were found to be 2.9 and 0.21 kg/ MJ, respectively. The results of optimization of energy input showed that using existing energy inputs, the yield of wheat can be increased by 32.2% in small farms, 25.5% in medium farms and 6.4% in large farms. Also, the existing level of yield of wheat could be obtained while reducing the total energy inputs by 15.6% in small farms, 5.4% in medium farms and 4.1% in large farms. The results indicated that the rate of forms of direct, indirect, renewable and non-renewable energy have found to be 28.8%, 71.2%, 26.1% and 73.9% of total energy input, respectively.

Key words: Energy productivity, Fertilizers, Iran, Renewable energy, Wheat

Agriculture constitutes 10.9% of the GDP and 21.9% of the total employment in 2009 (Central Intelligence Agency 2010). Energy use in agricultural production has become more intensive due to the use of fossil fuel, chemical fertilizers, pesticides, machinery and electricity to provide substantial increases in food production. Efficient use of energy is one of the principal requirements of sustainable agriculture. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery, and other natural resources. However, intensive use of energy causes problems threatening public health and environment. Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production system.

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), soybean, maize and wheat in Italy (Sartori *et al*. 2005), wheat, maize, sorghum in United States (Franzluebbers *et al*. 1995), apple in Iran (Rafiee *et al*. 2010), cucumber in Iran (Mohammadi and Omid 2010), kiwifruit production in Iran (Mohammadi *et al*. 2010), onion in Pennsylvania (Moore 2010) and coriander, lettuce, radish and spinach in Colombia (Bojaca and Schrevens 2010). To get higher productivity, the farmers, in general, use their resources in excess and inefficiently, particularly when these are priced low or free or are available in plenty. The excess use of resources and scope to increase the productivity or conserve the energy input without affecting the productivity, thereby enhancing the efficiency of energy use, has been viewed by many researchers (Kutala 1993, Refsgard *et al*. 1998, Mobtaker *et al*. 2010, Beheshti Tabar *et al*. 2010). Some researchers advised custom hiring (Dhavan and Mittal 1987) and shifting resources from one category of farms to another category to utilize the excess capacity (Sharma and Tewari 1985), whereas others suggested zone specific recommendations, as energy use to raise the crop mainly depends on the agro-climatic

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zones (Mittal 1993). Most of the studies were based on selective inputs in physical terms. So, the present study deals with output-input energy use in wheat production and optimization of the energy inputs.

The aim of this study was to determine the total amount of input-output energy used in wheat production and to optimize the energy inputs.

MATERIAL AND METHODS

The study was carried out in 150 wheat producer in Marand Township, Iran. The Township is located in the northwest of Iran, within 38° 07' and 38° 56' north latitude and 45° 15' and 45° 50' east longitude. Data were collected from the growers by using a face-to-face questionnaire. The data collected belonged to the production period of 2007–08. Sample farms were randomly selected from the villages in the study area by using a stratified random sampling technique. The sample size was calculated using the Neyman method (Yamane 1967) with the farms classified into three groups as small (<=1 ha), medium (1< <=3 ha) and large farms (>3 ha). The permissible error in the sample size was defined to be 5% for 95% confidence and the sample size was calculated as 150 farms. The total energy per production unit (ha) was established by the addition of the partial energies of each input referenced to the unit of production. Energy inputs were human labor, Diesel fuel, machinery, farmyard manure, irrigation, chemical fertilizers consisting of nitrogen (N), phosphate (P_2O_5) and potassium (K_2O). To estimate the energy of the inputs, expressed in MJ ha^{-1}, the energy equivalents in Table 1 were utilized.

The energy- use efficiency, the energy productivity, the specific energy and net energy were calculated using the following formulae (Mohammadi *et al*. 2008).

$$\text{Energy Ratio} = \frac{\text{Energy Output (MJ/ha)}}{\text{Energy Input (MJ/ha)}}$$

$$\text{Energy productivity} = \frac{\text{Grain Output (kg/ha)}}{\text{Energy Input (MJ/ha)}}$$

$$\text{Specific energy} = \frac{\text{Energy Input (Mj/ha)}}{\text{Grain Output (kg/ha)}}$$

$$\text{Net Energy (MJ/ha)} = \text{Energy Output} - \text{Energy Input}$$

Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm, and indirectly in the fertilizers and chemicals produced off the farm (Alam *et al*. 2005). Optimum energy use in agriculture is reflected in two ways, i.e. an increase in productivity with the existing level of energy inputs or conserving energy without affecting the productivity. Linear programming based on the concept of one-to-one functions was used and formulated to optimize the energy inputs as (Singh *et al*. 2004):

$$\text{Maximize } \sum \alpha_i Y_i \ (i = 1, 2, 3, ..., n)$$

Subject to

$$\sum \alpha_i X_{ji} \le \bar{X}_J \quad (j = 1\text{–}10)$$

$$\sum \alpha_i = 1$$

$$\sum \alpha_i (\sum X_{ji}) \le \sum \bar{X}_j$$

$$X_{ji} \ge 0$$

$$\alpha_i \ge 0$$

Where $\bar{X}_j$ is the weighted mean of the j^{th} energy use (j = 1-10) and $\sum X_{ji}$ is the total energy use by the i^{th} farmer. Farmers who fulfilled the above constraints and contributed to the optimal solution were assigned weightage (α) according to their effectiveness of energy input use. Optimized levels of energy input use to get the existing productivity level of wheat were computed using parametric programming by reducing the level of total energy input ($\sum \bar{X}_j$).

Table 1 Energy equivalent of inputs and outputs in agricultural production

Input	Unit	Energy equivalent (MJ/ unit)	Reference
A. Inputs			
Human labor	h	1.96	Mohammadi *et al*. (2008)
Machinery	kg	62.7	Mohammadi *et al*. (2008)
Chemical fertilizers	kg		
Nitrogen		66.14	Mohammadi *et al*. (2008)
Phosphate		12.44	Mohammadi *et al*. (2008)
Potassium		11.15	Mohammadi *et al*. (2008)
Manure	tons	303.1	Mohammadi *et al*. (2008)
Chemicals	kg	120	Mohammadi *et al*. (2008)
Seeds	kg	14.7	Singh (2002)
Diesel fuel	l	56.31	Mohammadi *et al*. (2008)
Water for irrigation	m^3	1.02	Mohammadi *et al*. (2008)
B. Outputs			
Grain wheat	kg	14.7	Singh (2002)
Straw	kg	12.5	Singh (2002)

RESULTS AND DISCUSION

Analysis of input –output energy use in wheat production

The amount of inputs used in wheat production, energy equivalent of inputs and outputs and energy indexes (energy ratio, energy productivity, specific energy and net energy) are shown in Tables 2, 3 and 4, respectively. Table 2, shows that the average seed used in wheat production was 205 kg /ha in the research area. Average human labor used in wheat production was 249.5 /ha of which 40.2% was devoted to harvesting. Since small farms are harvested by hand for all operations especially harvesting, it request much workers.

Table 2 Amounts of inputs and outputs in wheat production

Inputs	Farm size groups (ha)			Average
	Small	Medium	Large	
1.Human labour (h/ ha)	254.9	257	236.5	249.5
Land preparation	38.7	27.3	29.6	31.9
Seeding	4.4	4.6	4.8	4.6
Fertilizer application	11.9	13.3	12.8	12.7
Spraying	2.9	3	2.9	3
Irrigation	63.6	67.7	73.6	68.3
Harvesting	106.6	112.8	81.6	100.3
Transporting	26.8	28.3	31.2	28.8
2.Machinery (h ha^{-1})	29.2	30.4	32.8	30.8
Land preparation	9.2	9.8	10.7	10
Fertilizer application	4.3	4.7	4.5	4.5
Spraying	2.1	1.9	2	2
Harvesting	2.3	2.5	3.5	2.8
Transporting	11.3	11.5	12.1	11.6
3.Diesel (l/ ha^{-1})	96.8	101.2	108.5	102.2
Land preparation	59.6	63.1	68.6	63.7
Fertilizer application	8.8	9.6	9.2	9.2
Spraying	4.1	3.7	4.03	3.9
Harvesting	1.4	1.4	2	1.6
Transporting	22.9	23.5	24.7	23.7
4.Fertilizers (Kg ha^{-1})	606.4	473.1	473.1	517.5
Phosphate (P_2O_5)	245.6	176.3	165.4	195.8
Nitrogen (N)	281.5	239.1	236.5	252.4
Potassium (K_2O)	79.3	57.7	71.2	69.4
5.Manure (Tons ha^{-1})	6	5.5	5.5	5.7
6.Chemicals (Kg ha^{-1})	2.6	2	2.3	2.3
7.Water (m^3 ha^{-1})	4534.1	4487.5	4544.1	4521.9
8.Seed (Kg ha^{-1})	205	205	205	205
B. Outputs				
1.Wheat grain (Kg ha^{-1})	4328	4519	4876	4564.4
2.Straw (Kg ha^{-1})	3127	3364	3601	3364

Table 3 Energy consumption and output in wheat production

	Farm size groups (ha)			Average	
	Small	Medium	Large	Amount	(%)
A. Inputs					
1. Human labor (h)	499.6	503.7	463.5	488.9	1.3
2. Machinery (h)	1832.1	1907.3	2056.6	1932	5.13
3. Diesel fuel (L)	5450.8	5698.6	6111.3	5753.6	15.3
4. Fertilizer (Kg)	22557.8	18650.6	18493.6	19900.7	52.8
Phosphate (P2O5)	3055.3	2193.3	2057.6	2435.3	6.5
Nitrogen (N)	18618.4	15814.1	15642.1	16691.5	44.3
Potassium (K2O)	884.2	643.3	793.9	773.8	2.1
5. Manure (tons)	1818.6	1667.05	1667.05	1717.6	4.6
6. Chemicals (Kg)	312	240	276	276	0.8
7. Water (m3)	4624.8	4577.3	4635	4612.3	12.2
8. Seed (Kg)	3013.5	3013.5	3013.5	3013.5	8
Total energy inputs (MJ)	40109.3	36258.02	36716.5	37694.6	100
B. Outputs					
1. Wheat grain (Kg)	63621.6	66429.3	71236.2	67095.7	-
2. Straw (Kg)	39087.5	42050	45012.5	42050	-
Total energy outputs (MJ)	102709.1	108479.3	116248.7	109145.7	-

Table 4 Energy indexes in wheat production

	Small farms	Medium farms	Large farms	Average
Energy ratio	2.6	3	3.2	2.9
Energy productivity (kg MJ^{-1})	0.18	0.21	0.23	0.21
Specific energy (MJ kg^{-1})	5.4	4.6	4.3	4.8
Net energy (MJ ha^{-1})	62599.8	72221.3	79532.2	71451.1

The amounts of fertilizers used in large farms were les than small farms with average of 517.5 kg /ha. Furthermore, with the application rate of 252.4 kg /ha, nitrogen had the highest portion among the fertilizers. Annual yield of farms increased from 4328 kg per hectare in small farms to 4 876 kg /ha in large farms whit average of 4 564.4 kg /ha.

Based on the energy equivalents of the inputs and outputs given in Table 3, the average total energy consumed per farm was calculated as 37.7 G/Jha. Because the operations (except land preparation) were mostly handmade in small farms, it used higher input energy in comparison to large farms. Chemical fertilizers were one of the highest energy consumption of the different operations that increased from 22.5 G/Jha in small farms to 18.5GJ/ ha in large farms. Furthermore, with the average application rate of 19.9 G/ Jha, nitrogen had the highest portion (44.3%) among the fertilizers. The machinery and diesel energy consumption were 1.9 and 5.7 G/Jha and decreased as the farm size increased. Irrigation consumes 12.2% of total energy followed by seed and manure energy, 8% and 4.6% respectively, during production period. Based on Table 4, the energy output-input ratio was estimated at 2.9 and increased as the farm size increased. The main reason of lower energy ratio in small farms was chemical fertilizers consumption especially high nitrogen. Chemical Fertilizer consumption per unit field in small farms was higher compared to that of medium and large farms. Also, energy productivity in small, medium and large farms was 0.18, 0.21 and 0.23 kg/MJ, respectively. Specific energy and net energy was estimated at 4.8 MJ/ kg and 71.4 kg/ ha, respectively.

Shahin *et al*. (2008), calculated energy ratio and productivity in their study as 3.13 and 0.16 kg /MJ, respectively. The results showed that total energy input and output was 38.3 and 120 GJ/ ha, respectively which in comparison to results of this research, it seems that energy

Table 5 Actual use and optimum requirement of energy inputs (MJ/ha) in different levels of wheat production

	Small farms			Medium farms			Large farms		
Yield (kg/ha)	actual	optimum	%*	actual	optimum	%*	actual	optimum	%*
Labor	4 328	5 722	32.2	4 519	5 672	25.5	4 846	5 155	6.4
Machinery	499.6	377	-24.5	503.7	503.7	0	463.5	463.5	0
Diesel	1 832.1	1 673.3	-8.7	1 907.3	1 787.5	-6.3	2 056.6	1 849.7	-10.1
Seed	5 450.8	4 806.3	-11.8	5 698.6	5 698.6	0	6 111.3	6 111.3	0
Manure	3 013.5	3 013.5	0	3 013.5	2 940	-2.4	3 013.5	3 013.5	0
Phosphate	1 818.6	1 818.6	0	1 667.1	881	-47.2	1 667.1	1 026.3	-38.4
Nitrogen	3 055.3	2 236.6	-26.8	2 193.2	1 906.6	-13.1	2 057.6	1 382.1	-32.8
Potassium	18 618.4	14 695.5	-21.1	15 814.1	15 814.1	0	15 642.1	15 642.1	0
Chemicals	884.2	834.6	-5.6	643.4	643.4	0	793.9	793.9	0
Water	312	311.9	0	240	240	0	276	276	0
Total input energy	4 624.8	4 104.5	-11.3	4 577.3	3 875.3	-15.3	4 635	4 635	0
	40 109.3	33 870.5	-15.6	36 258	34 290.1	-5.4	36 716.5	35 193.4	-4.1

*: percent of change in comparison to actual use.

requirement in wheat production was in similar condition in northwest of Iran. In other researches, the results showed that total energy input for wheat production in conservation farming and organic farming were as 27.95 and 11.39, GJ / ha, respectively (Sartori *et al*. 2005), for apple production were 50,700 MJ/ ha (Rafiee *et al*. 2010).

Total mean energy input as direct, indirect, renewable and non-renewable forms were calculated. The share of direct input energy was 28.8% in the total energy compared to 71.2% for the indirect energy. The research results shown that on average the non-renewable form of energy input was 73.9% compared to 26.1% for renewable energy.

Optimization of energy inputs

The results of solving linear programming model for optimization of energy input in different levels of wheat production were given in Table 5. The results showed that the maximum attainable yield at optimal use of the existing resources was higher than the actual observed yield in all levels of production. The use of optimum energy revealed that there exist greater scope to increase the productivity; as the farmers could increase average yield by 32.2%, 25.5% and 6.4% in small, medium and large farms respectively, by using the same level of inputs through better management of the farm.

The results revealed that the farmers in all levels of production used higher energy than the optimum. This indicated that the existing productivity level in all levels of production could be achieved even by reducing the existing energy use levels by 15.6% in small farms, 5.4% in medium farms and 4.1% in large farms.

The results showed that the farmers of small farms used 8.7% machinery, 26.8% phosphate, 21.1% nitrogen and 5.6% potassium higher than optimum. Another hand, it can be save the energy consumption by optimum use of human labour, water for irrigation and diesel fuel by 24.5%, 11.3% and 11.8%, respectively. Also, the farmers of this level of production harvested the full potential of other resources. Optimal amounts in medium farms indicated that farmers in this level of production used 13.1% phosphate, 47.2% manure, 6.3% machinery and 15.3% water higher than the optimum. It can be saved energy consumption in large farms by 32.8% phosphate, 38.4% manure and 10.1% machinery, in terms of optimum use of resources.

The subject of this work was to investigate the output–input energy and to optimize energy consumption in wheat production of Marand region, Iran. From the current study it was concluded that: (i) total energy input in wheat production was obtained to be 37694.6 MJ /ha of which fertilizers was 52.8%, followed by diesel fuel (15.3%),. (ii) On an average, energy ratio, energy productivity, specific energy and net energy were found to be 2.9, 0.21 kg /MJ, 4.8 MJ /kg and 71 451.1 MJ /ha, respectively. The energy indexes of the large farms were higher than those of the small and medium farms.,(iii) the use of optimum energy implied that the farmers in all levels of production used higher energy than the optimum. This indicated that the existing productivity level in all levels of production could be achieved even by reducing the existing energy use levels by 15.6% in small farms, 5.4% in medium farms and 4.1% in large farms, and (iv) more energy saving could be achieved with proper management of energy inputs and crop rotation such as growing the leguminous plants which stabilize the nitrogen in the soil can decrease its consumption. So, fertilizers energy could be reduced if the recommended fertilizing applications were practiced.

AUTHOR: cross check all References with Text

REFERENCES

Alam M S, Alam M R and Islam K K. 2005. Energy Flow in Agriculture: Bangladesh. *American Journal of Environmental*

Sciences **1**(3): 213–20.

Beheshti Tabar I, Keyhani A and Rafiee S. 2010. Energy balance in Iran's agronomy (1990-2006). *Renewable and Sustainable Energy Reviews* **14**(2): 849–55.

Bojaca´ C R and Schrevens E. 2010. Energy assessment of peri-urban horticulture and its uncertainty: Case study for Bogota, Colombia. *Energy* **35**(5): 2109–18.

Central Intelligence Agency, the world fact book. 2010. See also < https://www.cia.gov/library/publications/the-world-factbook/geos/ir.html>

Dhawan K C and Mittal J P. 1987. Utilisation pattern of available sources on Indian farms—a case study. (*in*) *Proceedings of the National Conference on Energy in Production Agriculture and Food Processing*, pp 52–97 Punjab Agricultural University. Ludhiana.

Franzluebbers A J and Francis C A. 1995. Energy output-input ratio of maize and sorghum management systems in Eastern Nebraska. *Agriculture, Ecosystems and Environment* **53**(3): 271–8.

Kutala S S. 1993. Application of frontier technology to wheat crop grown on reclaimed soils. *Indian Journal of Agricultural Economics* **48**(2): 226–36.

Mittal J P. 1993. Comparative energy requirements in wheat cultivation under different technology levels in India. *Economic Affairs* **38**(4): 201–10.

Mobtaker HG, Keyhani A, Mohammadi A, Rafiee S and Akram A. 2010. Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran. *Agriculture, Ecosystems and Environment* **137**(3): 367–72.

Mohammadi A and Omid M. 2010. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. *Applied Energy* **87**(1): 191–6.

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

Mohammadi A, Tabatabaeefar A, Shahin S, Rafiee S and Keyhani A. 2008. Energy use and economical analysis of potato production in Iran a case study: Ardabil province. *Energy Conversion and Management* **49**(12): 3566–70.

Moore S R. 2010. Energy efficiency in small-scale biointensive organic onion production in Pennsylvania, USA. *Renewable Agriculture and Food Systems*. (in press).

Mrini M, Senhaji F and Pimentel D. 2001. Energy analysis of sugarcane production in Morocco. *Environment, Development and Sustainability* **3**(2): 109–26.

Rafiee S, Mousavi Avval S H and Mohammadi A. 2010. Modeling and sensitivity analysis of energy inputs for apple production in Iran. *Energy* **35**(8): 3301–6

Refsgaard K, Halberg N and Kristensen E S. 1998. Energy utilization in crop and dairy production in organic and conventional livestock production systems. *Agricultural Systems* **57**(4): 599–630.

Sartori L, Basso B, Bertocco M and Oliviero G. 2005. Energy Use and Economic Evaluation of a Three Year Crop Rotation for Conservation and Organic Farming in NE Italy. *Biosystems Engineering* **91**(2): 245–56.

Shahin S, Jafari A, Mobli H, Rafiee S and Karimi M. 2008. Effect of farm size on energy ratio for wheat production: a case study from Ardabil province of Iran. *American-Eurasian Journal of Agricultural & Environmental Sciences* **3**(4): 604–8.

Sharma L R and Tewari S C. 1985. Effective use of resources in farming. *Productivity* **25**(4): 405–9.

Singh G, Singh S and Singh J. 2004. optimization of energy inputs for wheat crop in Punjab. *Energy Conversion and Management* **45**(3): 453–65.

Singh J M. 2002. On farm use pattern in different cropping systems in Haryana, India. Master of Science. International Institute of Management, University of Flensburg, Germany.

Yamane T. 1967. *Elementry Sampling Theory*. Englewood Cliffs, New Jersey, USA: Prentice-Hall Inc.