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Energy Use in Wheat Production (A Case Study for Saveh, Iran)

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Abstract: This paper examines the energy consumption of wheat production in Iran (Saveh area). This study was conducted over 17.833 hectares of irrigated wheat fields and 15.500 hectares of dry land wheat in Saveh city, Iran, in the harvest year of 2003-2004. The data was collected from three different sources: questionnaire, literature reviewand field measurement. Total energy consumption for wheat in irrigated farming systems and dry land farming systems was estimated 51,587 and 12,543 MJ/ha. The average operational energy consumption for cultivation of irrigated farming system and dry land farming system was 36107 and 6067 MJ/ha, respectively. The maximum energy consumed in operational wheat production was about 28,301 MJ/ha for irrigated farming systems, including irrigation and It was 3,582 MJ/ha for dry land farming, including tillage, .Energy consumption in the production of one-kilogram of wheat, in irrigated farming and dry land farming systems, on average, was 13.5 MJ/kg and 10.4 MJ/kg, respectively. The average values of estimated energy ratio for wheat in irrigated farming system and barley dry land farming system were 1.9 and 2.5, respectively.

Key words: Energy consumption · Production · Agricultural machinery · Wheat · Operation · Inputs

INTRODUCTION

Saveh has a population of 275,000 over an area of 10,279 square kilometers. The annual rainfall is from 100 to 400 mm; the temperature varies from -20°C to 40°C [1].

Wheat is one of the major crops for feeding human beings. In 2003, Saveh contained a total of 150,000 hectares of arable land. About 11% of arable land was used for irrigated wheat production and about 10% was used for dry land wheat production.

Crop yields and food supplies to consumers are directly linked to energy; that is, sufficient energy is needed in the right form at the right time for this purpose [2]. Agricultural operations include all farming operations that occur after the land is cleared and developed, such as tillage, planting, fertilizing, pest control, harvestingand transportation. Energy needed for agricultural production is about 3 % of the national energy consumption in developed countries and about 5% to 6% in developing countries [3]. The entire food system (production, processing, storage, transportationand final operation) may require 15 to 20%, or even more as compared to developing nation's energy [4]. In agriculture and other economic activities, energy consumption in crop production has increased in developed countries more than developing countries as a result of population growth, migration from rural areas to urban areas and design and improvement of new production techniques [5]. Between 1945 and 1985, total energy consumption increased 500% and the petroleum and natural gas consumption increased about 900%, while the world population growth increased 200% [6].

Fossil fuel energy can either be replaced with new sources of energy, or it can be optimized in an applied manner. One way to optimize energy consumption is to determine the efficiency of methods and techniques used [7]. There should be a plan for energy consumption, otherwise, with the current population growth; the present life style will be unsustainable. Energy consumption has been reduced by 1.3-4.9% in developed industrial countries [8]. Use of diesel in tractors and diesel engines for various operations contributed 27.2% of the total energy input under irrigated conditions; and electricity which was used in irrigation only supplied 12.7% energy [8]. Therefore, one should recognize the input elements and recommend a method in order to control them. Since, there are different methods to estimate the energy consumption, comparison and evaluation of results are difficult. For example, some research consider human labor as an energy input in their calculation, however, many others do not [9-12]. Furthermore, general international agreement on how to

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estimate input energy is difficult. The lack of reliable data for each country and region often forces researchers to take values from other countries without making adjustment for different circumstances in those countries [13]. Agricultural energy use can be classified as either direct or indirect [14]. The primary means of direct energy use on-farm involves the consumption of fuels such as diesel, furnace oil, gasoline, other petroleum products, electricity and wood. Indirect energy is the energy used to create and transport farm inputs, such as pesticides, feed, machinery, seeds and fertilizers. Indirect energy accounts for 70% of total energy use on dairy and hog farms and about 50% on arable farms [15,16].

The objectives of this study was to determine the energy consumption in wheat production based on field operations, in irrigated and dry land farming systems. Field size and its effects on energy and fuel consumption were studied in detail on the farms.

METHODOLOGY

The survey was conducted to identify farmers' attitudes and opinions towards energy consumption. There were two demographic variables: farm type and size. Farmers were asked to introduce all sources of energy used in their farms.

The inputs for energy analysis in wheat production include operational energy consumption (field machinery, labor, irrigation pumps (electrical or fuel)and irrigation)and also indirect energy: fertilizer, pesticidesand seed. Therefore, two major parts of this study, operations and energy sources, are examined.

Operations: Energy consumption in wheat production operation, such as tillage machinery, planters, fertilizer broadcasters, sprayers, irrigation, transportation and harvesting, were determined in both farming systems, except for irrigation in dry land farming system. The number and duration of operations, the rate of seed, pesticide, fertilizerand amount of human labor were investigated using a questionnaire and calculating personal interviews with farmers. Randomly selected farm owners completed the questionnaire. For each operation, fuel consumption was measured in the field by filling the tractor tank twice, before and after each operation and the difference recorded. From the literature review and ASAE standards, equivalent energy inputs were determined for all input and output parameters for wheat. For comparison of energy consumption in different field sizes, irrigated farm land was surveyed based on three different size categories: less than two hectares, between two to ten hectares and greater than 10 hectares. However, dry land was categorized as between two to ten hectares and greater than 10 hectares due to extensive variation and the existence of larger field sizes in the irrigated land. Irrigation energy consumption was included with water pumping from the water surface to land surface (water well depths varies from 40 to 156 meter in vast area of Saveh)and energy used for surface irrigation.

Energy Sources:

Human: Human labor is used for almost every task on the farm, from driving machinery, maintenance, repair, irrigation, sprayingand fertilizer to management. Although, in the future, human labor will reduce in the fully mechanized (mechatronic) farms to almost nil. Currently, the energy output for a male worker is about 1.96 MJ/hr and 0.8 MJ/hr for a female. In children, it is about 0.98 MJ/hr, half of a man's output energy [8]. One must recognize that human energy is the most expensive form of energy in field operations.

Fuel: Diesel fuel is the main source of fuel in agricultural machinery as well as motor pumps and water pumps. Fuel consumption was determined before and after any operation by filling the tractor fuel tank and recording the difference after the operation was completed. MF 285 tractors were used for most operations. This test was repeated six times for each operation. The energy output for analysis was determined from fuel consumption per operation of one hectare of land times the fuel equivalent energy per liter as shown in equation 1.

$$\text{Energy (input) / hectare} = \text{Operation fuel consumption (L/ha)} \times \text{Fuel energy (MJ/L)} \quad (1)$$

For self- propelled combines, the fuel was measured separately and was 27 L/ha. Fuel consumption for air spraying was determined by fuel used in one year divided by the land areas, hectare, which was approximately 2 L/ha.

Fertilizer: The use of mineral fertilizer is the fastest growing form of energy consumption in agricultural production. Nitrogen fertilizer is by far the most important mineral fertilizer in world agriculture, both in the amount of plant nutrient used and in energy requirements. The most popular fertilizers are ammonium phosphate and supper phosphate. Nitrogen (N) fertilizer is very energy intensiveand on the other hand, phosphate (P_2O_5) and

Table 1: Fertilizer consumption (Kg/ha) for Wheat production

Acreage category(ha)	N	P
Irrigation farming(Kg/ha)		
Less than 2	208	200
2 to 10	246	181
Greater than 10	247	162
Dry land farming(Kg/ha)		
2 to 10	215	239
Greater than 10	229	148

Table 2: Seed consumption (kg) for different wheat production

Acreage category(ha)	Max	Min	Average
Irrigation farming(Kg/ha)			
Less than 2	350	120	264
2 to 10	350	100	247
Greater than 10	350	100	230
Dry land farming(Kg/ha)			
2 to 10	150	90	126
Greater than 10	150	90	126

potash (K_2O) do not require high feedstock energy. The energy output for one kilogram of nitrogen and phosphate are 78.1, 17.4 MJ/kg respectively [5]. Unfortunately, most farmers have believed that the yield would increase only with a higher rate of ammonium. However; only a few amount of the nitrogen applied to crops is absorbed by the plant itself, which is a function of soil type, temperature and rainfall [17]. Table 1 shows the average amount of nitrate consumption in different products.

Agrichemical: Three different methods of pest control i.e. chemical, mechanicaland biological are usually applied to control or eliminate fungi, insectsand weeds in a farm. Most farmers have preferred the chemical method. The most common chemicals which are used in farms in order to fight against disease, insectsand weeds on a wheat farm, are 2-4-D, Linden, Paraquat and Mali tune, in order. In Saveh, aeroplane spraying (air spraying) and tractor-mounted spraying are used to apply chemicals to fight against crop farm diseases.

Seed: Clean and proper seeds were provided in packages from seed produce companies and private institutes. However some farmers still used their own seeds.

On average, 229 kg/ha and 126 kg/ha seed was planted for wheat production in irrigated and dry land farms, respectively. Normally, a range of 100 to 350 kg/ha seeds is applied on the irrigated farms and a range of 90 to 150 kg/ha for dry land farms. Different factors, such as planting system, variety of seed and germination rate, influence on amount of seed in different wheat. Table 2 shows average of seed for wheat production. From the table, it may be found that the seed used in large-scale farming systems are more efficient. The average energy output per one kg of seeds is 13 MJ/kg for wheat production [5].

RESULTS AND DISCUSSION

Energy Consumption in Wheat Production for One Hectare of Land: Energy consumption in wheat production for one hectare of land has two main components; operations and energy sources.

Operations: Operational energy consumption in wheat production includes: tillage, planting, fertilizer distribution, spraying, irrigation, transportation and harvesting; they were determined in irrigated farming systems as shown in Table3. Except for irrigation, all other operations were considered for energy consumption of dry land farming system as shown in Table 3.The energy consumption in wheat production per hectare was much higher in irrigated farming land system than in dry land system. It was around 51,587 MJ for irrigated farming and 12,543 MJ for dry land farming.

The operational energy consumption was much higher in irrigated land due to tillage, fertilizer and irrigation operations; however, the major difference is due to irrigation operation with 78.4% of total operational energy consumption. Operational energy consumptions in both systems are shown in Figure 1.

Tillage is ranked high in both systems. Tillage operational energy consumption, ranked first with 59% in dry land farming.

Operational energy consumption was greater for the small-scale farming system than other categories. Energy consumption was 37,951 MJ/ha for less than two hectares and 36,897 MJ/ha for farming between two to ten hectares and 26,172 MJ/ha for greater than ten hectares. Therefore larger field sizes should be practiced.

Energy Sources: The direct and indirect energy sources for irrigation and dry land farming were determined as shown in Table 4. The main source of energy was fuel consumption with 36,472 MJ/ha for irrigated farming systemand 6,067 MJ/ha for dry land farming system as shown in Figure 2. By far, fuel is the most important source of energy. Fertilizer is second most important

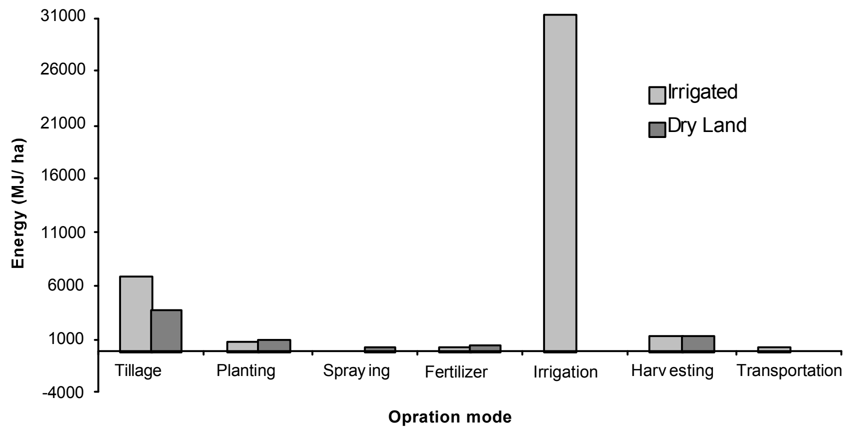

Fig. 1: Operational energy consumption for wheat production

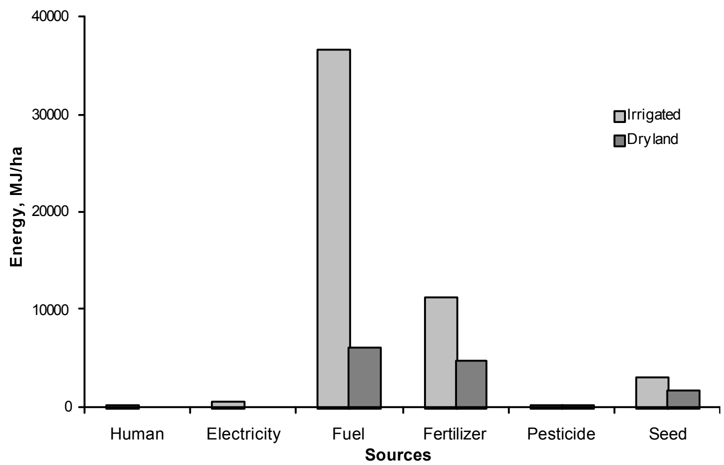

Fig. 2: Energy source consumption for irrigated and dry land-farming systems for wheat production

source of energy in wheat production. Pesticide consumption was lower for dry land area than irrigation farming system due to larger field sizes and aerial spraying of pesticide. Fuel consumption is the important input elements in energy consumption; therefore, a detail study should be done of service and maintenance of tractors as well as of the managerial supervision methods used order to reduce the amount of energy consumed.

Energy Consumption for One–kilogram of Wheat Production: Energy consumption for one kilogram of wheat production was determined as shown in Table 5 and 6 based on the operation and sources for irrigated and dry land farming system. Based on operation, irrigation had the highest energy consumption at 78.4% for irrigated farming systems. As far as the source is concerned, the highest input was the fuel; fuel consumption for irrigated farming system and dry land farming system were 70.1 and 48.8% ,respectively. The energy consumption for producing one –kilogram wheat was much higher in irrigated farming land than in dry land. Tillage is ranked high in both systems. Tillage ranked first with 59%in dry land farming. Serious attention must be paid in order to control irrigation operation and tillage. Energy consumption for production of one kg of wheat in irrigated farming system were estimated 13.8, 12.1 and 14.1 MJ/ha for land less than two hectares, between 2 to 10 hectaresand greater than 10 hectares, respectively. On average, energy consumption for irrigated and dry land farming system was 13.4 and 10.4 MJ/kg as shown in Table 4.

Energy Ratio: Energy ratio was determined from output energy to input energy [5]. Fluck [9] analyzed this concept and stated that" the energy ratio can be applied to the use of energy in isolated societies, in which it is important that the output energy is greater than the input energy in order to assure their subsistence". Conforti and Giampietro [13]

Table 3: Energy consumption (MJ/ha) based on operations for wheat production

Acreage category(ha)	Tillage	Planting	Spraying	Fertilizer distributor	Harvesting	Irrigation	Transportation
Irrigation farming(MJ/ha)							
Less than 2	5446	679	58	281	1290	29836	358
2 to 10	5785	992	89	294	1107	27900	726
Greater than 10	4826	911	86	313	997	28360	265
Dry land farming(MJ/ha)							
2 to 10	3919	853	232	384	1290	--	73
Greater than 10	3552	836	109	1112	1290	--	106

Table 4: Energy consumption for wheat production, MJ/ha based on sources

	Direct energy MJ/ha			Indirect energy MJ/ha		
Acreage category(ha)	Human	Electricity	Fuel	Fertilizer	Pesticide	Seed
Irrigation farming MJ/ha						
Less than 2	124	871	37,986	9,934	128	3,385
2 to 10	126	656	37,158	1,0627	153	3,124
Greater than 10	148	621	36,183	1,1420	165	2,917
Dry land farming MJ/ha						
2 to 10	10	--	6,751	4,515	106	1,449
Greater than 10	12	--	6008	4,753	83	1,661

Table 5: Operational energy consumption (MJ/kg) in the production of one kilogram of wheat

Acreage category(ha)	Tillage	Planting	Spraying	Fertilizer distributor	Harvesting	Irrigation	Transportation
Irrigation farming(MJ/ha)							
Less than 2	1.43	0.18	0.02	0.07	0.34	7.85	0.09
2 to 10	1.35	0.23	0.02	0.07	0.26	6.51	0.17
Greater than 10	1.32	0.25	0.02	0.09	0.27	7.75	0.08
Dry land farming(MJ/ha)							
2 to 10	2.82	0.61	0.17	0.28	0.93	--	0.05
Greater than 10	2.99	0.70	0.09	0.09	1.09	--	0.09

Table 6: Energy consumption, MJ/kg based on sources for irrigated and dry land farming system

	Direct energy MJ/ha			Indirect energy MJ/ha		
Acreage category(ha)	Human	Electricity	Fuel	Fertilizer	Pesticide	Seed
Irrigation farming MJ/ha						
Less than 2	0.03	0.23	10.00	2.61	0.03	0.89
2 to 10	0.03	0.15	8.66	2.48	0.04	0.73
Greater than 10	0.04	0.17	9.89	3.12	0.05	0.80
Dry land farming MJ/ha						
2 to 10	0.01	--	4.86	3.25	0.08	1.04
Greater than 10	0.01	--	5.05	4.00	0.07	1.40

by using energy ratio, separated 75 countries into five clusters. They explained that land constraints, with respect to the total population size, rather than labor constraints, tend to be associated with comparatively higher energy requirements in agricultural production. Also they suggested that the output/input ratio may depend mostly on the average output/farmer and on overall population density. If the ratio is higher than one, the system is earning energy, whereas if it is less than one, the system is losing energy as shown in Table 7. On average, in both systems, equal amount of energy was input as output with the exception of larger field sizes where farmers had advantage over the input as shown in Table 7. Practically, the energy gain shows most farmers earn what they put in that make the system to fail in long run. Energy ratio for wheat production (bullock) in India

Table 7: Energy Ratio for Wheat Production

Acreage category(ha)	Output energy, MJ/ha	Input Energy, MJ/ha	ER
Irrigation farming MJ/ha			
Less than 2	103155.9	52432.4	2.0
2 to 10	109345.7	51846.8	2.1
Greater than 10	91180.0	51465.8	1.8
Dry land farming MJ/ha			
2 to 10	34877.8	12831.4	2.7
Greater than 10	30897.1	12518.7	2.5

Table 8: Yield and some of inputs in different clusters

	Less than 2 Hectare	Between 2 and 10 Hectare	Greater than 10 Hectare	Total
Yield (Irrigated system)	3.80	4.29	3.66	3.81
Yield (Dry Land system)	--	1.33	1.18	1.23
Farmer Age	50.29	50.74	50.87	50.65
Age of Tractor	8.94	13.18	14.27	12.33
Number of Paddocks	2.12	1.82	1.47	1.79
Distance from city	48.38	76.68	76.42	68.54

was 1.69 [3] which is 27.5% higher than the best ratio found in this study. A system of precision farming or precision management must be in place for Iranian farmers.

The average values of estimated energy ratio for wheat for irrigated farming system and dry land farming system were 1.9 and 2.5, respectively. Also table 7 shows, energy ratio was greater for the small-scale farming system than other categories, because in small farms, human energy was used more than the large-scale farming system.

Other Results: For better comparison different inputs were classified to three different clusters, Table 8 compares average of some inputs and yields in different clusters. It shows middle farms have better yield than other two groups, never the less there are not significant differences between farmer age in different groups. Furthermore, the average age of farmers (50 years) is more than the average age of society (24years)); therefore their ability to new practice is reduced.

Further more farmer in first group sell their production to nearest markets but farmer who have bigger farm have better opportunities to sell their production. The table shows by increasing the size of farms the number of paddocks reduce, its mean that the small farms, which are separated to another sections, can reduce efficiency more and more. On the other hand the farmers who have bigger farms use older tractors because they have better facilities and abilities for maintenance and repair.

CONCLUSION

Energy input in wheat production was similar for both systems, except the sources of energy consumption varied strongly in different systems. Also, graphs of energy sources and operational energy consumption illustrate most of fuel consumption is consumed in irrigation .Its means conversion of old diesel pumps to electric pumps can reduce energy and fuel consumption significantly.

By far, in the wheat production, fuel is the most important source of energyand fertilizer comes second; therefore, it is necessary to focus on fuel and fertilizer consumption more than other factors. A detail study of amount and methods, of fuel and fertilizer use needs to be undertaken in order to help reduce the energy consumptions.

Contrary to expectations, in some cases, by increasing the size of farms the efficiency didn't increase. Different factors such as management abilities of farmers can influence on energy consumption.

Given the findings of this study the most significant areas for improving overall energy efficiency on arable farms in

Saveh Area Are as Follows:

- Fertilizer management, particularly in relation to the use of urea, to reduce indirect energy requirements for fertilizer manufacture; (A serious educational workshop must be held about fertilizer consumption and method for the farmer. The method of fertilizer broadcasting and amount of the fertilizer used must be taken under study and guidance to managerial staff)
- Water management on irrigated farms, particularly using electric pumps instead of diesel pumps and using high pressure spray irrigation, to reduce direct use of electricity;
- Tractor and vehicle selection and operation to reduce direct use of diesel and petrol; better equipments and reduction of tractors passes in farms can reduce fuel consumption significantly. Also some educational workshops should be held about the operation, service and maintenance of different machinery for the farmers.

This study show, energy consumption per Kg in dry land farming system is less than irrigated farming system, nevertheless, in irrigated farming system, more energy was consumed per hectare.

REFERENCES

1. Safa, M. and A. Tabatabaeefar, 2002. Energy Consumption in Wheat Production, IACE 2002,Wuxi, China.
2. Karkacier, O., Z. Gokalp Goktolga and A. Cicek, 2006. A regression analysis of the effect of energy use in agriculture. Energy Policy., 34(18): 3796-3800.
3. Stout, B.A., 1990. Handbook of Energy for World Agriculture. London and New York. Elsevier Applied Science. 1-50: 95-101.
4. Stout, B.A., 1989. Energy in World Agriculture, Volume 5- Analysis of Agricultural Energy Systems. Amsterdam, London, New York and Tokyo. Elsevier.
5. Kitani, O., 1999. CIGR Handbook of Agricultural Engineering, Volume V - Energy and Biomass. Engineering. ASAE Publication.
6. Haldenbilen, S., 2003. Evaluation of Sustainable transport indicators for Turkey based on genetic algorithm approach. P.H.D. Thesis, Institute of Science and Technology, Pamukkale University, Denizli, Turkey.
7. Kitani, O., 1998. Energy and Environment in Agricultural Engineering Research. International Engineering Conference, Bangkok, Thailand.
8. Singh, S.M.J., 1992. Energy in Production Agriculture. India; Mittal Publishing Company.
9. Fluck, R.C., 1992. Energy in World Agriculture, Elsevier, Amsterdam., 6: 31- 37.
10. Sartori, L., B. Basso, M. Bertocco and G. Oliviero, 2005. Energy Use and Economic Evaluation of a Three Year Crop Rotation for Conservation and Organic Farming in NE Italy. Biosystems Engineering 91 (2): 245-256.
11. Hu¨lsbergen, K.J. and W.D. Kalk, 2001. Energy balances in different agricultural systems - can they be improved? The International Fertiliser Society Proceedings No: 476.
12. Saunders, C., 2006. Food miles-Comparative Energy/ Emissions Performance of New Zealand's agriculture Industry. Research Report No. 285. Agribusiness and Economics Research Unit (AERU). Lincoln University. New Zealand.
13. Conforti, P. and M. Giampietro, 1997. Fossil energy use in agriculture: an international comparison. Agriculture, Ecosystems and Environment, 65: 231-243.
14. Mohtasebi, S.S., M. Behroozi Lar, M. Safa and M.R., Chaichi, 2008. Comparison of Direct and Indirect Energy Coefficients for Seeding and Fertilizing in Irrigated Wheat Production, World Applied Sciences, 3(3): 353-358.
15. Meul, M, F. Nevens, D. Reheul and G. Hofman, 2007. Energy Use Efficiency of Specialized Dairy, Arable and Pig Farms in Flanders. Agric Ecosyst Environ; 119(1-2): 135-44.
16. Wells, C., 2001. Total Energy Indicators of Agricultural Sustainability: Dairy farming Case Study, Wellington: Ministry of Agriculture and Forestry. New Zealand.
17. Witney, B., 1988. Choosing and Using Farm Machines. Harlow, Essex, England New York: Longman Scientific and Technical, Wiley.

00. Lockeretz, W., 1977. Agriculture and Energy. Academic Press Publication. New York, San Francisco, London.