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ENERGY CONSUMPTION PATTERNS AND ECONOMIC ANALYSIS OF IRRIGATED WHEAT AND RAINFED WHEAT PRODUCTION: CASE STUDY FOR TOKAT REGION, TURKEY

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Abstract

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The aim of this study was to determine the input-output energy consumption and to make a cost analysis of both irrigated wheat and rainfed wheat production in Tokat province (Turkey). The results showed that the amount of energy consumed in irrigated wheat production was 13 205.90 MJ ha^{-1} and in rainfed wheat production was 14 134. 93 MJ ha^{-1}. In the surveyed farm holdings, the energy input-output ratio for the irrigated wheat was 3.80, while benefit-cost ratio was 0.81. The productivity of irrigated wheat was calculated to be 3.67. The energy input-output ratio for rainfed wheat was 2.51, while the benefit-cost ratio was 0.53. The productivity of rainfed wheat was calculated to be 2.43. About 77% of the total energy inputs used in irrigated wheat production was non-renewable, while only about 23% was renewable. The total energy input used in rainfed wheat production was non-renewable 75% and 25% renewable energy. This study suggested that diesel-oil and fertilizers were not efficiently used. Intensive input use in irrigated wheat and rainfed wheat raises some problems like environmental pollution and global warming.

Key words: input-output energy; wheat; fertilizer; productivity; economic analysis

Introduction

Approximately 35% of the population in Turkey lives in rural areas. The Turkish agricultural sector provides 12% of Gross National Products and 11% of total exports (DTM, 2005) so agriculture is obviously a sector with a major role in Turkish economy. Wheat growing, which has an important economic and strategic role, takes place at about three million farms and is a source of income for about 15 million people every year (Gul, 2004).

Because of the many varieties available, which can grow under many climatic and soil conditions, wheat is grown all around the world. According

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to the FAO (2005) statistics the most important wheat growers are China (97 Mton), India (72 Mton) and USA (57.3 Mton). Turkey occupies the eighth place in the world wheat growing rankings, with 21 million tons. Tokat province contributed 2.1% (434,000 ton) to Turkey's wheat production in 2005 (Tokat Provincial Directorate, 2005).

The main conditions for sustainable agriculture are: to reduce the dependence of agriculture on nature, to protect the natural resources, and to use safe agricultural techniques for humans and for the environment by efficient use of production factors. On the other hand, to increase production, to improve quality and to use energy efficiently is also very important. The increase in world population and prosperity levels are the main causes of the mass usage of energy. This energy usage damages human health and the environment, inducing global warming. As a result of these circumstances, achieving effective energy usage in agriculture is important for sustainable and environmentally friendly agriculture as well. To evaluate the energy usage efficiency in agricultural production activities, input-output analysis is widely used.

In this study input-output energy analyses were separately calculated for irrigated and rainfed wheat production. The reasons for this may be explained in two ways. Firstly, arable land is about 268 568 ha in Tokat, from which irrigated arable land is about 25% (66 887 ha). 54.7 % of the total arable fields in Tokat are used for wheat production and approximately 45 % of this wheat cultivation area is irrigated in May and June by the government or individuals (Tokat Provincial Directorate, 2005). According to the Tokat Soil and Water Resources Research Institute (2005) meteorology data the average rainfall of Tokat is 100 mm per year.

Secondly, there are many studies on energy usage pattern for agricultural crops (Esengun et al., 2007; Erdal et al., 2007; Yilmaz et al., 2005; Ozkan et al., 2004a; Ozkan et al., 2004b; Singh et al., 2002a; Singh et al., 2002b; De et al., 2001; Shrestha,1998; Singh et al, 1997; Yaldiz et al, 1993; Helsel,1992), such as wheat energy usage study (Canakci et al., 2004; Singh et al., 2003; Mandal et al., 2002; Singh et al., 1999; Singh et al., 1997; Hetz, 1992; Triolo at al., 1987; Singh et al., 2007). Worldwide, wheat is grown under either rainfed or irrigated conditions, but there is only one study about both irrigated and rainfed wheat (Tabatabaeefar and Safa, 2002).

For these reasons, energy consumptions and input-output relations, energy forms and economical analysis were calculated separately for irrigated and rainfed wheat production. Moreover energy usage, input costs and distribution of energy forms were explained by comparison of both wheat production methods.

Materials and Methods

Data used in the research came from the study which was done in 2006 by Altintas (Altintas, 2006). The data in this study pertains to the production term of the year 2006 and covers the inputs and their amounts which are used in the production of wheat under arid circumstances. Energy equivalencies for wheat production are given in Table 1. The data for the equivalences in Table 1 were gathered from various sources.

Basic information on energy inputs and irrigated and rainfed wheat yields were entered into Excel spreadsheets. Based on the energy equivalents of the inputs and output (Table 1), the metabolizable energy was calculated. Energy ratio (energy use efficiency) and energy productivity were calculated (Maddal et al., 2002; Singh et al., 1997):

$$Output-input\ \ raito = \frac{Energy\ output\ (MJ\ ha^{-1})}{Energy\ input\ (MJ\ ha^{-1})}$$

$$Output-input\ \ raito = \frac{Energy\ output\ (MJ\ ha^{-1})}{Energy\ input\ (MJ\ ha^{-1})}$$

The input energy was divided into direct, indirect, renewable and non-renewable energy (Yilmaz et al., 2005). Indirect energy included

Table 1
Energy equivalent of inputs and outputs in agricultural production

Input	Unit	Energy equivalent,MJ unit $^{-1}$	References
Human Labour	h	1.96	Erdal et al,2007 ; Singh, 2002
Machinery	h	62.7	Esengun et al, 2007 ; Erdal et al, 2007
Chemical fertilizers	kg		
Nitrogen (N)		66.14	Esengun et al, 2007 ; Erdal et al, 2007
Phosphorus (P_2O_5)		12.44	Esengun et al, 2007 ; Erdal et al, 2007
Herbicides	kg	238	Esengun et al, 2007 ; Erdal et al, 2007
Seeds	kg	15.7	Singh, 2002
Diesel-oil	L	56.31	Esengun et al, 2007 ; Erdal et al, 2007
Water for irrigation	m^3	0.63	Esengun et al, 2007 ; Erdal et al, 2007
Output	kg	14.7	Singh, 2002

energy embodied in seeds, fertilizers and pesticides, while direct energy covered human power and diesel used in the wheat production process. Non-renewable energy includes diesel, chemical, fertilizers and machinery, and renewable energy consists of human power and seeds. Furthermore, indirect and non-renewable energy includes water for irrigated wheat. Single crop budget analysis was used to calculate costs and operating costs. Alternative cost analyses were used for production costs. Proportions and weighted arithmetic average were used for evaluations.

Table 2
Management practices for irrigated and rainfed wheat

	Irrigation Wheat	Rainfed Wheat
Land preparation period	October-April	October-April
Average tilling number	2	2
Sowing period	October-December	September-January
Harrow	October-December	September-January
Average number of harrow	1	2
Fertilization period	October-April	September-January
Average number of fertilization	2	1
Irrigation period	May-June	--
Average number of irrigation	1	--
Spraying period	May-June	March-May
Average number of spraying	1	1
Harvesting period	July	June-August
Average number of harvesting	1	1

Results and Discussion

Table 2 shows the agronomic practices during the growing process of irrigated and rainfed wheat crops, along with the periods relevant to these activities. The earliest operation for irrigated and rainfed wheat growing was soil tilling performed from October to April. The harvest period for irrigated wheat was July; for rainfed wheat it was June-August. For soil cultivation and tilling practices in the surveyed area, tractors are extensively used with the help of appliances such as plows, crowbars and harrows. Knapsack sprayers are used for the application of pesticides. For the harvest, combine harvesters are used for the irrigated wheat and scythes are used for the rainfed wheat.

Table 3 shows the inputs used in irrigated wheat production in the surveyed area and their energy equivalents with output energy rates and their equivalents. The results revealed that 33.7 h of human power and 10 h machinery power are required per hectare of irrigated wheat production in the researched area. Of the total human power, 29.97% is used for field preparation, 58.16% for cultivation and 11.87% for harvest operations. About 76% of the machine power used for irrigated wheat growing was exerted for field preparation, 8% for cultivation and 16 % for harvesting-transportation. The amount of fertilizers used for irrigated wheat growing was 107 kg ha^{-1}. The amount of other inputs used for irrigated wheat growing such as herbicides and diesel-oil were 2 kg and 53.02 L,

Table 3

Energy consumption and input-output relationship for irrigated wheat production

Inputs	Quantity per unit area, ha	Total energy equivalent, MJ	Percentage, %
Human labour (h)	33.7	66.05	0.5
Land preparation	10.1	19.8	0.15
Cultural practices	19.6	38.42	0.29
Harvesting	4	7.84	0.06
Machinery (h)	10	627	4.75
Land preparation	7.6	476.52	3.61
Cultural practices	0.8	50.16	0.38
Harvesting-Transportation	1.6	100.32	0.76
Chemical fertilizers (kg)			
Nitrogen (N)	52	3 439.28	26.04
Phosphorus (P_2O_5)	55	684.2	5.18
Herbicides (kg)	2	476	3.6
Seeds (kg)	190	2 983.00	22.59
Diesel-oil (lt)	53.02	2 985.56	22.61
Water for irrigation (m^3)	3.087	1 944.81	14.73
Total Energy (MJ)		13 205.90	100
Yield (kg/ha)	3.41	50 127.00	
Energy output-input ratio		3.8	
Energy Productivity (kg seed MJ ha^{-1})		0.26	

Table 4

Energy consumption and input-output relationship for rainfed wheat production

Inputs	Quantity per unit area, ha	Total energy equivalent, MJ	Percentage, %
Human Labour (h)	116.7	228.73	1.62
Land preparation	12	23.52	0.17
Cultural practices	5.9	11.56	0.08
Harvesting	98.8	193.65	1.37
Machinery (h)	17.7	1 109.79	7.85
Land preparation	8.8	551.76	3.9
Cultural practices	0.9	56.43	0.4
Harvesting- Transportation	8	501.6	355
Chemical fertilizers (kg)			
Nitrogen (N)	65	4 299.10	30.41
Phosphorus (P_2O_5)	69	858.36	6.07
Herbicides (kg)	2	476	3.37
Seeds (kg)	206	3 234.20	22.88
Diesel-oil (lt)	69.77	3 928.75	27.79
Water for irrigation (m^3)	0	0	
Total Energy (MJ)		14 134.93	100
Yield (kg/ha)	2.41	35 427.00	
Energy output-input ratio		2.51	
Energy Productivity (kg seed MJ ha^{-1})		0.17	

respectively.

The total amount of energy used for various practices in the process of irrigated wheat production was calculated to be 13 205.90 MJ ha^{-1}.

The main sources of total energy used in the production process were fertilizers (31.22%), diesel-oil (22.61%) and seeds (22.59%). Energy generated by diesel-oil was particularly used by tractors during soil tilling, cultivation and harvesting-transportation. The rates of other inputs in the total amount of energy such as machinery, herbicides and human power were 14.73%, 4.75%, 3.60% and 0.50%, respectively. In the surveyed farms, the average yield was 3410 kg ha^{-1} and the rate of energy was 3.80.

Table 4 shows the inputs used in rainfed wheat production in the area of survey and their energy equivalents with output energy rates and their equivalents.

The results revealed that 116.7 h human power and 17.7 h machinery power are required per hectare of rainfed wheat production in the researched area. As mentioned above, combined harvesters are used for harvesting-threshing operations for irrigated wheat, while for rainfed wheat harvesting is done manually by scythe. Thus, more manpower is required for rainfed wheat, mainly because of the sloped land used, which prevents the use of combined harvesting machines for harvest operations. On the other hand, machine power in harvesting-threshing operations is calculated higher than for rainfed wheat production because of the thresher

Table 5
Energy values for cultivating wheat in previous researches

Countries	Year	Total energy, MJ ha-1	Energy ratio	References
India	2002	15 290	7.2	Maddal et al, 2002
India (various zones/ regions)	1997	8 496- 18 881	3.87 – 5.71	Singh et al, 1997
India (various zones/ regions)	2007	10 777 - 21 032	2.2 – 5.9	Singh et al, 2007
India	2003	17 042	8	Singh et al, 2003
Punjab (different agro-climatic zones)	1999	13 063- 17 932	3.69 – 6.71	Singh et al, 1999
Chilean	1992	12 745 – 16 379	2.74 – 4.69	Hetz,1992
Italy	1987	23 990	-	Triolo et al, 1987
Antalya / Turkey	2005	18 680	2.8	Canakci et al, 2005

Table 6
Total energy inputs in the forms of direct, indirect, renewable and non-renewable for irrigated wheat and rainfed wheat production

Crop	Total energy input,	Energy forms, MJ/ha			
	MJ/ha	Direct energy[a]	Indirect energy[b]	Renewable energy[c]	Non-renewable energy[d]
Irrigated Wheat	13205.90	3051.61 (23.11)	10154.29 (76.89)	3049.05 (23.09)	10156.85 (76.91)
Rainfed Wheat	14134.93	4157.48 (29.41)	9977.45 (70.59)	3462.93 (24.5)	10672 (75.5)

[a]Includes human labour, diesel

[b]Includes seeds, fertilizers, chemicals, machinery (includes water for irrigated wheat)

[c]human labour, seeds

[d]Includes diesel, chemicals, fertilizers, machinery (includes water for irrigated wheat)

[e]Figures in parentheses indicate percentage of total energy input

usage in the threshing process.

Of the total human power, 10.28% is used for field preparation, 5.6% for cultivation and 84.66% for harvest-bled operations. About 49.72% of the machine power used for rainfed wheat growing was exerted for field preparation, 5.08% for cultivation and 45.20 % for harvesting-transportation.

The amount of fertilizers used for rainfed wheat growth was 134 kg ha^{-1}. The amount of other inputs used for irrigated wheat growing such as herbicides and diesel-oil were 2 kg and 69.77 L, respectively. The total amount of energy used for various practices in the process of rainfed wheat production was calculated to be 14 134.93 MJ ha^{-1}.

The main sources of total energy used in the production process were: 36.47% fertilizers, 27.79% diesel-oil and 22.88% seeds. The rates of other inputs in the total amount of energy such as machinery, herbicides and human power were 7.85%, 3.37%, 1.62%, respectively.

In rainfed wheat growing, the average yield was 2 410 kg ha^{-1} and the rate of energy was 2.51. The total energy and the rate of energy in the Tokat region are very close to those given in previous studies, as seen in Table 5. Irrigating the wheat crop, high diesel consumption and the use of more

Table 7
Economic analysis of irrigated wheat

Cost of production	$/ha	%
Soil preparation and sowing	279.16	23.24
Maintenance work	39.88	3.32
Harvesting- Threshing- Transportation	87.6	7.29
Seeds	78.43	6.53
Fertilizers (Nitrogen)	60.66	5.05
Fertilizers (P_2O_5)	46.53	3.87
Herbicides	5.6	0.47
Water of irrigation	57.37	4.78
Total	655.23	54.54
Common Cost		
Various cost	32.74	2.73
Land rent	379.98	31.63
Interest of capital	101.45	8.44
Management cost	32.04	2.67
Total	546.21	45.46
TOTAL COST	1 201.44	100
Yield (kg/ha)	3 410.00	
Side crop ($/ha)	272.86	
Cost of production ($/ha)	928.58	
Cost of production ($/kg)	0.27	
Wheat price ($/kg)	0.22	
Gross production value ($/ha)	750.2	
Benefit cost ratio	0.81	
Productivity	3.67	
Net return ($)	-178.38	

(1US$ = YTL 1,43 in average monthly 2006)

Gross production value = total wheat value (wheat yield (kg ha^{-1}) multiplied by wheat price ($ kg^{-1})

Cost of production ($ ha^{-1}) = Total cost - side crop value

Cost of production ($ kg^{-1}) = Cost of production ($ ha^{-1})/ wheat yield (kg ha^{-1})

Benefit cost ratio = Gross production value ($/ha) / Cost of production ($/ha)

Productivity = Wheat yield (kg/ha) / Cost of production ($/ha)

Net return = Gross production value ($/ha) - Cost of production ($/ha)

Table 8
Economic analysis of rainfed wheat

Cost of production	$/ha	%
Soil preparation and sowing	349.26	28.97
Maintenance work	12.03	1
Harvesting- Threshing- Transportation	335.27	27.81
Seeds	85.01	7.05
Fertilizers (Nitrogen)	52.47	4.35
Fertilizers (P_2O_5)	42.26	3.51
Herbicides	5.6	0.46
Water of irrigation	0	0
Total	881.9	73.15
Common cost		0
Various cost	44.08	3.66
Land rent	145.67	12.08
Interest of capital	101.8	8.44
Management cost	32.18	2.67
Total	323.73	26.85
TOTAL COST	1 205.63	100
Yield (kg/ha)	2 410.00	
Side crop ($/ha)	213.74	
Cost of production ($/ha)	991.89	
Cost of production ($/kg)	0.41	
Wheat price ($/kg)	0.22	
Gross production value ($/ha)	530.2	
Benefit cost ratio	0.53	
Productivity	2.43	
Net return ($)	-461.69	

(1US$ = YTL 1.43 in average monthly 2006)

fertilizer in the Italian conditions increases the total energy requirements (Triolo et al., 1987).

The total energy input for irrigated and rainfed wheat as direct, indirect, renewable and non-renewable forms is given in Table 6.

As it can be seen from Table 6, the total energy input consumed for irrigating the wheat crop could be classified as non-renewable (76.91%), indirect (76.89%), direct (23.11%) and renewable energy (23.09%). Similarly the total energy input consumed for the rainfed wheat crop could be classified as non-renewable (75.50%), indirect (70.59%), direct (29.41%) and renewable energy (24.50%). Both for the irrigated wheat crop and the rainfed wheat crop, the high rate of non-renewable energy and indirect energy indicates an intensive use of fertilizers, herbicides and machinery in the farms. Energy inputs and yield levels of irrigated

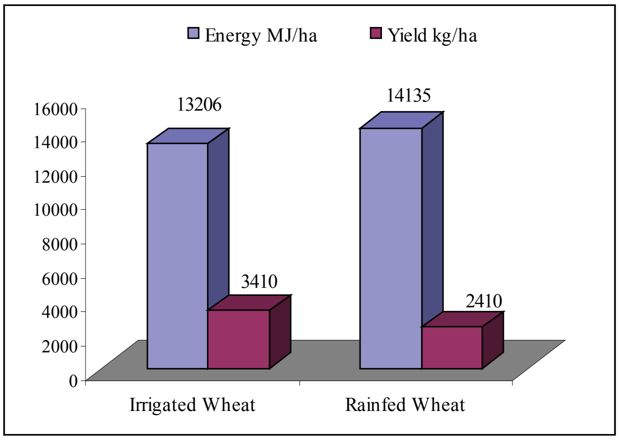

Fig. 1. Energy input and yield level of irrigated wheat and rainfed wheat

wheat and rainfed wheat are shown in Figure 1.

The cost of the inputs used in the production of irrigated wheat and the gross value of production were calculated and shown in Table 7.

Within the cost of production, the highest cost portion belongs to land rentals at 31.63 %, followed by soil preparation and sowing with 23.24 %, and capital interest at 8.44 % for irrigated wheat production. Common costs are calculated as 45.46 %, and direct cost is calculated as 54.54%. Because the common cost ratio is relatively high in the total cost for the irrigated wheat production, benefit/cost ratio is calculated as lower than one (0.81).

While the production costs is 928.58 $ per hectare, the value is 0.27 $ per kg. Gross production value is 750.20 $. Due to the fact that the common cost ratio is relatively high, total cost is calculated as higher than gross production value.

On the other hand, in the surveyed farm holdings, the productive energy consumption was 3.80, while profit-expense ratio was 0.81. The productivity of irrigated wheat production was calculated to be 3.67.

The cost of the inputs used in the production of rainfed wheat and the gross value of production were calculated and shown in Table 8.

For rainfed wheat production the highest cost elements are soil preparation and sowing at 28.97 %, followed by harvesting-threshing and transportation as 27.81%, and land rental at 12.08%.

Within the cost elements, common costs are calculated as 26.85 %, and direct cost is calculated as 73.15%. Because of the common cost ratio is relatively high in the total cost for rainfed wheat production, the benefit/cost ratio is calculated as 0.53, that is, lower than one.

While the production costs is 991.89 $ per hectare, the value is 0.41 $ per kg. Gross production value is 530.20 $. Since the common cost ratio is relatively high, total cost is calculated as higher than gross production value.

On the other hand, in the surveyed farm holdings, the productive energy consumption was 2.51, while profit-expense ratio was 0.53. The productivity of rainfed wheat production was calculated to be 2.43.

Conclusions

This research examined the input and output usage levels for rainfed and irrigated wheat in the Tokat region of Turkey. According to the research results, the energy value of the total inputs for irrigated wheat production is 13 205.90 MJ ha^{-1} and for rainfed wheat production it is 14 134.93 MJ ha^{-1}. Because the usage levels of manpower, machines, fertilizers and diesel oil inputs are dense for rainfed wheat production, the total energy requirement is determined to be higher than for irrigated conditions. From this point of view, it can be said that either higher yields are obtained or less energy inputs are required for the irrigated wheat production.

Chemical fertilizer energy contributes greatly to the used energy, followed by diesel and seed energy, for both wheat production classes. Because fertilizer is used indiscriminately in the researched area, without soil analysis, the calculated level of fertilizer energy was high. On the other hand, for the soil preparation, cultural activities and transportation machinery are highly used in the production process, so diesel energy usage also is calculated as high. The energy input/output ratio is determined as 3.80 for irrigated wheat, 2.51 for rainfed wheat production. Because the total energy input is high and yield is low for the rainfed wheat production, input/output ratio was calculated as lower than for irrigated wheat production. Furthermore, with the financial analysis, the energy productivity is calculated as 0.26 for irrigated wheat and 0.17 for rainfed wheat production.

In Tokat city, with its developing economy mainly based on agriculture, irrigation infrastructures like ponds and irrigation canals are not well developed. Farmers find the irrigation charges very unreasonable. On the other hand, investments in irrigation are given weight in light of rising temperatures due to global climate changes in most cities of Turkey. In this context a fund of TL 250000 is devoted for the Almus – Akarcay underground irrigation system project in Tokat. It will make it much more inviting to cultivate agricultural products under hydrated conditions and the efficient use of energy incomes can be established when those investments and projects are put into place.

Energy management becomes more important if the energy needed must be economical, sustainable and productive and this study suggests that diesel-oil and fertilizers were not efficiently used. This may bring about problems which threaten the environment and may eventually cause adverse effects on human health. Moreover, this can increase the production costs. It is recommended that efficient and more reasonable production systems are developed, extensions of the recent techniques are employed, and more efficient use of energy by the farmers is emphasized.

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