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Renewable and Nonrenewable Energy Use Pattern of Rainfed Wheat Agroecosystems in Iran

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Abstract: Energy management in agricultural systems is a determinant of sustainability of production systems. Applying renewable energy resources in agricultural production systems decreases dependence of production systems to non-renewable inputs, reduces fossil fuel consumption as well as improves production systems' sustainability by increasing energy use efficiency. This study was conducted in summer 2009 to assess the effect of renewable energy resources on the energy use efficiency of rainfed wheat systems in Kangavar county, western Iran. Data was collected applying questionnaire via face to face interviews with 60 farmers in summer 2009. Results showed total energy input and output in these agroecosystems were 14255.5 and 56161.7 MJ/ha, respectively. The highest share of input energy was recorded for N fertilizer (32%) which is a nonrenewable resource. Total mean energy input as renewable and nonrenewable forms in rainfed wheat production systems were 27.4 and 72.6%, respectively. Energy efficiency (energy output/energy input) of studied systems was 3.94. Comparison of application of renewable energy resource and energy use efficiency showed that energy use efficiency was higher in these systems than systems that applied more nonrenewable energy input. Results revealed that replacing nonrenewable energy resource by renewable inputs will increase energy use efficiency of these agricultural systems.

Key words: Energy use efficiency · Renewable energy · Sustainable agriculture · Wheat

INTRODUCTION

Wheat (Triticum aestivum L.) is main cereal cultivated throughout the world and Iran along with rice, barley and maize. The production of wheat is about 13484,456 tons/year in Iran and the cultivation land area is about 6647367 hectares in 2009 [1]. 33.46% of wheat production in Iran is related to rainfed wheat agroecosystems [1]. Rainfed wheat cultivation land area in Kangavar is about 26160 ha with 1.9 tons/hectare grain yield in 2009 that its one of the important region producer for rainfed wheat.

Today; about Energy, being the capacity to do work, is at the heart of all human activities, especially those concerning the production of goods and services [2]. With increased world growing population and energy limitation will have difficult supplied energy in future. Energy is convention exchange in agroecosystems. Agriculture and food systems rely on a variety of energy sources, including renewable and non-renewable resources such as fossil fuels as well as human and animal labour. Energy is used not only in planting, cultivating and harvesting of crops and animal products, but also in the manufacture and transport of inputs such as pesticides, fertilizers and machinery and in processing, packaging and distribution of final products [3]. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil fuels preservation and air pollution reduction [4]. Therefore energy analysis of agricultural ecosystems seems to be a promising approach to investigate and assess the energy use efficiency, environmental problems and their relations to sustainability [5].

Using of renewable energy resource in agroecosystems can be improved energy use efficiency and sustainability of production systems. Because renewable resources are not finite (as fossil fuels), destroyer environmental impacts, does not rely on imported fuels and many are available in all farming systems [6]. Also higher ratio of renewable energy to nonrenewable energy consumed is major purpose of sustainable agriculture.

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Meany researcher studied energy use for agriculture production in different rejoins for example [2-7]. For this purpose those calculated input-output energy, energy productivity, specific energy and energy forms of direct, indirect, renewable and non-renewable. But each one of themes was not evaluated the effects of consumed renewable energy resource on the energy efficiency of productions systems.

The objective of the present study was analyzing input-output, examine energy use efficiency, estimated shear of renewable and nonrenewable energy sources in the total process production in rainfed wheat agroecosystems. That can be affective in good management agroecosystems for realization sustainability in agriculture.

Nomenclature:

M_{pe}	Energy consumption of the machine
G	Mass of the machine
T	Economic life
C_{ef}	Effective field capacity
DE	Direct energy
IDE	Indirect energy
RE	Renewable energy
NRE	nonrenewable energy

Methodology: In this study, wheat growers were surveyed in Kangavar, Iran. The Kangavar region is located in the western of Iran, within 33° 4' and 35° 17' north latitude and 45°25' and 48° 6' east longitudes. The climate of this case study (data relating to the 1989-2009 period) is characterized by an annual average rainfall of 403 mm, distributed 44.3% in winter and 55.7% spring and fall. The annual average temperature is 14.2° C, with a monthly maximum of 27°C in July and a minimum of -1°C in January. Data was collected by 120 farmers from 60 of 72 villages of the region using a questionnaire. In other 12 villages, wheat production is not conventional. Farmers selected randomly from the village and data were collected by face to face interview. Some other information was collected from regional agricultural departments in Kangavar.

Total energy input and output in rainfed wheat production systems was collected by using questionnaires and data analysis. Basic information on energy inputs and wheat yields were entered into Excel spreadsheets were calculated that shown in Table 1.

The energy consumption of tractors and other agricultural machinery were calculated using the following equation [8];

$$M_{ep} = \frac{G * MP}{T * C_{ef}} \quad (1)$$

Where M_{ep} is the energy consumption of the machine per unit area, MJ ha^{-1}; G is the mass of the machine, kg; Mp is the production energy consumption of the machine, MJ kg^{-1}; T is the economic life, h; and C_{ef} is the effective field capacity, ha h^{-1}.

Energy use efficiency, specific energy, energy productivity and energy density were determined by using standard equations [11, 12];

$$EUE = \frac{OE}{IE} \quad (3)$$

Where EUE is the energy use efficiency; OE is the energy output, MJ ha^{-1}; IE is the energy input, MJ ha^{-1}.

$$SE = \frac{EI}{Y} \quad (4)$$

Where SE is the specific energy, MJ h^{-1}; Y is wheat yield, $tonh^{-1}$.

Table 1: Energy equivalents of input and output in agricultural systems

	Unit	Energy equivalents	Reference
A. Inputs			
1.Human Labour	H	1.96	[9,10]
2.Machinery	h	62.7	[9,11]
3.Diesel fuel	L	51.33	[9,11]
4. Chemical Fertilizer			
(a) Nitrogen	Kg	66.14	[9,11]
(b) Phosphate(P2O5)	kg	12.44	[9,10]
5.Pesticides	kg	120	[11,12]
6.Seed(seed+ fungicides)	Kg	17.6	[13]
B. Output			
1.Grain Wheat	Kg	14.7	[7,14]
2.Straw	Kg	12.5	[7,14]

$$EP = \frac{Y}{EI} \quad (5)$$

Where EP is the energy productivity, $KgMJ^{-1}$.

In order to analysis energy can be energy requirements in agriculture systems divided into four groups: direct and indirect, non-renewable and renewable energy resource. Direct energy was includes human labor and diesel fuel. Also indirect energy was includes seeds, fertilizers, pesticides and machinery energy [15, 16]. Non-renewable energy includes diesel, chemicals, fertilizers and machinery and renewable energy consists of human labour and seeds [11].

RESULTS AND DICTATION

In this study, data used were collected in period of summer 2008 from rainfed wheat agroecosystems in the Kangavar region. In the researched area, average size of surveyed agroecosystems was 8.65ha and about 42% of this amount in year was related to rainfed wheat cultivation.

Analysis of Input-output Energy Use in Rainfed Wheat Agroecosystems: Table 2 shows the inputs used in rainfed wheat agroecosystems in the area of survey and their energy equivalents with output energy rates and their equivalents. The results showed that 18.02 h human labour and 7.51 h machinery power are required per hectare of rainfed wheat production in the researched area. Also amount of diesel fuel, N fertilizers, Phosphate (P_2O_5), pesticides and seeds used for rainfed wheat growth were 80.09 Lha^{-1}, 68.5, 53, 1.46 and 220 kg ha^{-1} respectively.

The total amount of energy used for various practices in the process of rainfed wheat production was calculated to be 14255.5 $MJha^{-1}$. Khan *et al* [17] reported that total energy input in wheat, rice and barely were 100346.4,161586 and 64314 $MJha^{-1}$ respectively. Adnan *et al.* [7] calculated the energy inputs for irrigated and rainfed wheat in Turkey that were 13205.90 and 14134.93 $MJha^{-1}$. The highest share of total input energy in rainfed wheat production ecosystems were recorded for N fertilizer, diesel fuel and seeds with 31.8%, 31.6% and 27.2% respectively. The rates of other inputs in the total amount of energy such as Phosphate (P_2O_5), machinery, pesticides and human power were 4.6, 3.4, 1.2 and 0.2%, respectively. The similar results were reported in literature that the energy input of chemical fertilizers has the biggest share of the total energy input in rainfed wheat production. Such as irrigated and rainfed wheat [7], irrigated wheat [18], sugar beet [9].

In rainfed wheat agroecosystems investigated, the average grain yield and straw were 1967.5 and 2179.16 kg ha^{-1} and calculated total energy output were 28922.25 and 27239.5 MJ ha^{-1}. In total amount of output energy in rainfed wheat agroecosystems in Kangavar region was 56161.7 MJ ha^{-1}. This amount was for wheat, rice and barely 100346.4, 161586and 64314$MJha^{-1}$ [17] respectively, for rainfed and irrigated wheat 35427 and 50127 $MJha^{-1}$[7].

Table 2: Energy equivalents of input and output in rainfed wheat production systems

Quantity (input and output)	Quantity per unit area (ha)	Total energy equivalents ($MJha^{-1}$)	Percentage of total energy (%)
A. Inputs			
1.Human Labour(h)	18.02	35.32	0.2
2.Machinery (h)	7.51	470.87	3.4
3.Diesel fuel(L)	80.09	4509.86	31.6
4.ChemicalFertilizer(kg)			
(a) Nitrogen	68.5	4530.59	31.8
(b) Phosphate(P2O5)	53	659.32	4.6
5.Pesticides(kg)	1.46	177.09	1.2
6.Seed(kg)	220	3872	27.2
Total energy input(MJ)		14255.05	100
B. Output			
1.Grain Wheat(kg)	1967.5	28922.25	51.5
2.Straw(kg)	2179.16	27239.5	48.5
Total energy input(MJ)		56161.7	100

Table 3: Different form and indicators of energy use in rainfed wheat production systems

Indicators	Unit	Quantity for rainfed wheat
Inputs energy	$MJha^{-1}$	14255.05
Output energy	$MJha^{-1}$	56161.75
Grain yield	$Kgha^{-1}$	1967.5
Straw yield	$Kgha^{-1}$	2179.16
Energy use efficiency		3.94
Specific energy	$MJkg^{-1}$	7.25
Energy productivity	$KgMJ^{-1}$	0.14
Net energy	$MJha^{-1}$	41906.7
Directed energy[1]	$MJha^{-1}$	4545.18(31.9%)
Indirected energy[2]	$MJha^{-1}$	9709.8(68.1%)
Renewable energy[3]	$MJha^{-1}$	3907.32(27.4%)
Non-renewable energy[4]	$MJha^{-1}$	10347.73(72.6%)
Total energy input	$MJha^{-1}$	14255.05(100%)

[1]Includes human labour, diesel. 2 Includes seeds, fertilizers, pesticides, machinery.

[3]Includes human labour, seed. 4 Includes diesel, pesticides, fertilizers, machinery.

The analysis of input-output energy shows that try to improve the overall energetic efficiency should be focused on fertilizer, fuel and seed consumption in rainfed wheat agroecosystems. However, significant reduction of chemical fertilizers is not considered feasible as it would decrease production yields. A saving in diesel fuel by improving tractor operating performance may be possible and recommended [11].

Energy Indicators Analysis in Rainfed Wheat Agroecosystems: Table 3 shows the energy indicators in rainfed wheat agroecosystems. The energy use efficiency, energy productivity, specific energy and net energy in the Kangavar region are listed in Table 3. Energy efficiency (energy output-input ratio) in this study was 3.94 and energy productivity calculated as 0.14kg.MJ^{-1} in the study area. This means that 0.14 kg of output obtained per unit energy. Energy use efficiency can be increased by growth of yield or reduce input energy. Adnan *et al* [7] calculated energy use efficiency and energy productivity for irrigated wheat3.8, 0.26 and in rainfed wheat were 2.51, 0.17 respectively.

Specific energy was 7.25 MJ.kg^{-1}. This means that 7.25 MJ is needed to obtain 1 kg of rainfed wheat. This amount were for irrigated wheat 10.43 [13], for sugar beet 0.65 [9] and 5.87 for rainfed wheat in Turkey [7]. Net energy in rainfed wheat agroecosystems was 41906.7 MJ.ha^{-1}. This means that the amount of output energy is elder than input energy. This amounts was reported for irrigated wheat production of Iran 123317.48[19], for sugar beet 982090.5[9] and for kiwifruit 16354.23$MJha^{-1}$ [11] respectively. Each amount economical yield was higher as well as specific energy is higher. Because produced more energy output per unit of input energy.

Energy Forms in Rainfed Wheat Agroecosystems: The total energy input for rainfed wheat as direct, indirect, renewable and non-renewable energy forms are shown in Table 3. The share of 68.1% of the total energy input was depended on the indirect form, whereas 31.9% of the total energy input was in the direct form. The share of renewable energy was 27.4% in the total energy compared to 72.6% for the non-renewable energy. Therefore, it revealed that the rate of indirect energy was greater than that of direct energy consumption in rainfed wheat production. This result was in agreement with the results of other researches. The rate of non-renewable energy also was higher than that of renewable energy consumption in surveyed farms; Similarly the total energy input consumed for the rainfed wheat crop could be classified as non-renewable (72.6%), indirect (68.1%), direct (31.9%) and renewable energy (27.4%).Intensity of non-renewable energy consumption resulted from fertilizer, diesel fuel and machinery use in production.

Energy use efficiency can be increased by reduce nonrenewable energy resource and important use of renewable energy resource as well as therefore sustainable agriculture systems already uses less fossil fuel based inputs and has a better carbon footprint [6] than standard agricultural practices wider use of renewable energy sources, increase in energy supply and efficiency of use can make a valuable contribution to meet sustainable energy development targets.

CONCLUSIONS

In this study, energy used of inputs and output in rainfed wheat production was analyzed to estimate energy use pattern of rainfed wheat cultivation in Kangavar regions of Iran. For this purpose, data were collected from 60 rainfed wheat producer which were selected based on random sampling method. From the present study following conclusions are drawn:

- The average of energy input in rainfed wheat production was to be 56161.7 MJ ha^{-1}, mainly due to total fertilizer (31.8%).
- The energy use efficiency, specific energy, energy productivity and net energy of rainfed wheat production Were 3.94, 7.25 MJ kg^{-1}, 0.14 kg MJ^{-1} and 41906.7 MJ ha^{-1} respectively.
- The share of total input energy as renewable and nonrenewable forms were 27.4 and 72.6% respectively.

In the outrance sustainable agriculture systems production can point the way to wisely balancing energy efficiency with economic and environment factors in all stages from production to consumption, which will ultimately determine both the social and financial viability of adopting energy saving practices. Finally, using of renewable energy resource in agroecosystems can be improved energy use efficiency and sustainability of production systems.

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