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Full Length Research Paper

Economical analysis and energy use efficiency in alfalfa production systems in Iran

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Energy use efficiency is one of the key indicators for developing more sustainable agricultural practices. For this purpose energy use in the production of alfalfa was studied in Kermanshah province, western Iran in summer 2010 by analysis of energy flow in this crop. Data was collected using questionnaires and face to face interviews with 63 farmers. Total inputs and outputs of alfalfa systems were calculated and converted to their energy equivalent. Results showed that total energy input and output in alfalfa agroecosystems were 49689.59 and 240072.7 MJ/ha, respectively. The highest share of input energy was recorded for diesel fuels (43.1%), electricity (24.36%) and N fertilizer (12.2%). The results also showed that energy use efficiency, specific energy, energy productivity and net energy were 4.83, 3.68, 0.27 and 190383.11 MJ/ha respectively. Total mean energy input as renewable and nonrenewable forms were calculated to be 10.24 and 89.76% respectively. Economic analysis showed the total cost of production and net return for one hectare of alfalfa production were around 889.32 and2140.96 $ respectively. Accordingly, the benefit/cost ratio and productivity (dividing alfalfa yield by total production cost) were estimated 2.41 and 15.19 Kg/$. It was concluded that energy management at farm level could be improved to give more efficient and economic use of energy.

Key words: Energy use efficiency, alfalfa, economical analysis, sustainable agriculture.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most important forage crops that in addition to forage production have important effects in N fertilizer and soil amplification. Growing legumes offers the opportunity to add N to the soil system biologically (Entz et al., 2002) which reduces fossil fuel costs associated with mineral fertilizer. Alfalfa is the major forage crop in Iran. The land area under alfalfa production in Iran is about 6333092 ha which produces 5208541.19 ton of alfalfa in 2010 (Anonymous, 2010). Kermanshah province is one of the major alfalfa-producing provinces in which about 10% of alfalfa production in Iran is provided from this province (Anonymous, 2010).

(Streimikiene et al., 2007) and efficient use of energy is

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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. The vast majority of energy used in crop production is in the form of fossil fuels (Fluck and Baird, 1980). Three main components of an on-farm energy balance are energy use, energy output and energy use efficiency (Hoeppner et al., 2005). Energy consumption should account for all energy inputs, including energy to manufacture farm machinery, fertilizer, pesticides and energy embodied in diesel fuels, electricity and seed. The second component of the energy balance is energy output. By all accounts, food energy output will need to increase in the future in order to satisfy a growing human population (Smil, 2005). The final energy component of interest is energy-use efficiency. Energy use is one of the key indicators for developing more sustainable agricultural practices one of the principal requirements of sustainable agriculture

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

Equipment /inputs	Unit	Energy equivalents	References
A. Inputs			
1. Human Labour	H	1.96	Bojaca and Schrevens (2010), Mohammadi et al. (2010)
2. Machinery	h	62.7	Samavatean et al. (2010), Mobtaker et al. (2010)
3. Diesel fuel	L	51.33	Erdal et al. (2007), Mohammadi et al. (2010)
4. Chemical Fertilizer	kg		
(a) Nitrogen		66.14	Esengun et al. (2007), Rafiee et al. (2010)
(b) Phosphate(P_2O_5)		12.44	Esengun et al. (2007), Rafiee et al. (2010)
(c) Potassium(K_2O)		11.15	Esengun et al. (2007), Rafiee et al. (2010)
6. Pesticides	kg	120	Samavatean et al. (2010), Mohammadi et al. (2010)
7. Electrisity	kWh	3.6	Kizilaslan (2009), Rafiee et al. (2010)
8. Water for irrigation	M^3	0.63	Hatirli et al. (2006), Esengun et al. (2007)
9. Seed	kg	6.9	Nagy (1999), Hoeppner et al. (2005)
B. Output			
1. Alfalfa forage	kg	17.77	Nagy (1999), Hoeppner et al. (2005)

(Kizilaslan, 2009). The main aim of this study was to determine energy use in alfalfa production, to investigate the efficiency of energy consumption and to make an economic analysis of alfalfa in Kermanshah province of Iran.

MATERIALS AND METHODS

Data were collected from 63 alfalfa farms all through Kermanshah province by using a face to face questionnaire in summer season of 2010. This province is located in the western part of Iran, within 34.5° north latitude and 48.1° east longitude. The random sampling of production agroecosystems was done within whole population and the size of each sample was determined by using Equation 1 (Kizilaslan, 2009):

$$n = \frac{N \times s^2 \times t^2}{(N-1)d^2 + s^2 \times t^2} \quad (1)$$

In the formula, n is the required sample size, s is the standard deviation, t is the t value at 95% confidence limit (1.96), N is the number of holding in target population and d is the acceptable error.

The permissible error in the sample size was defined to be 5% for 95% confidence and the sample size was calculated as 63 farms. The sources of mechanical energy used on the selected farms included diesel for tractors computed on the basis of total fuel consumption (L ha^{-1}) in different operations. The energy consumed was calculated using conversion factors (1L diesel = 56.31 MJ) and was expressed in $MJha^{-1}$ (Rafiee et al., 2010). Was calculated amount of Consumed electricity energy by Equations 2: **(**Bala and Hussain, 1992**)**:

$$E = p.\ t.\ c \quad (2)$$

where: E is electricity energy (MJ), P is the pump power (kWh), t is the during pump working, and C is the energy equivalent (1 kWh= 3.6 MJ).

Basic information on energy inputs and alfalfa yield were entered into Excel spreadsheets and then energy equivalent were calculated according Table 1.

The energy use efficiency, specific energy, energy productivity and net energy were calculated according to Equations 3 to 6, respectively (Hatirli et al., 2008; Mohammadi et al., 2010):

$$\text{Energy use efficiency} = (\text{output energy } [MJha^{-1}]) / (\text{input energy } [MJha^{-1}]) \quad (3)$$

$$\text{Specific energy} = (\text{input energy } [MJha^{-1}]) / (\text{Forage yield } [Kgha^{-1}]) \quad (4)$$

$$\text{Energy productivity} = (\text{Forage yield } [Kgha^{-1}]) / (\text{input energy } [MJha^{-1}]) \quad (5)$$

$$\text{Net energy} = \text{output energy } (MJha^{-1}) - \text{input energy } (MJha^{-1}) \quad (6)$$

The input energy was divided into direct, indirect, renewable and non-renewable energies (Kizilaslan, 2009; Samavatean et al., 2010). Direct energy covered human labor, diesel fuel, water for irrigation, and electricity used in the alfalfa production while indirect energy consists of seeds, pesticide, fertilizers, and machinery energy. Renewable energy consists of human labor and seeds and nonrenewable energy includes diesel, pesticide, fertilizers, electricity and machinery. Also In the last part of the research, economic analysis of alfalfa production was investigated. The input and output were calculated per hectare and then, these input and output data were multiplied by their costs. Net return (total production costs minus total production value), benefit/cost ratio and productivity (by divided total alfalfa yield/total production costs) were calculated (Samavatean et al., 2010).

RESULTS AND DISCUSSION

In this study, data used were collected from 63 alfalfa production agroecosystems in the Kermanshah province Alfalfa production in this region is mechanized and highly

Table 2. Energy inputs, outputs and the ratio in alfalfa production.

Equipment /inputs(unit)	Quantity per unit area (ha)	Total energy equivalents	%
A. Inputs			
1. Human Labour(h)	316.92	621.16	1.25
2. Machinery(h)	40.9	2564.43	5.51
3. Diesel fuel(L)	380.37	21418.63	43.1
4. Chemical Fertilizer(kg)			
(a) Nitrogen	92	6084.88	12.2
(b) Phosphate(P_2O_5)	57.5	721.62	1.45
(c) Potassium(K_2O)	138	1578.72	3.18
5. Chemical (kg)	1.5	180	0.36
6. Electrisity(Kwh)	3368.5	12053.34	24.3
7. Water for irrigation(m^3)	6563.7	4135.13	8.32
8. Seed(kg)	48.07	331.68	0.67
Total energy input		49689.59	100
B. Output			
1. alfalfa forage yield(kg)	13510	240072.7	100

dependent on commercial input. The mean of alfalfa harvesting in this region is 4 stage per year. Also in this agroecosystems was used in operations of tillage, transporting, fertilizing and spraying by Massey Ferguson 285 tractor, 75 hp.

Analysis of input–output energy use in Alfalfa production

The inputs used in alfalfa production and their energy equivalents and output energy equivalent are illustrated in Table 2. About 316.92 h human labour and 40.9 h machinery power and 380.37 L diesel fuel for total operations were used in agroecosystems alfalfa production on a hectare basis. The use of nitrogen fertilizer, phosphorus and potassium were 92, 57.5 and 138 kg per one hectare respectively. Also 3368.5 kWh electricity power in this systems was used for water pumping and irrigation. The total energy equivalent of inputs was calculated as 49689.59 $MJha^{-1}$. The highest share of this amount was reported for diesel fuel (43.1%), electricity (24.3%), and nitrogen fertilizer (12.2%) respectively.

The similar results were reported in literature that the energy input of diesel fuel has the biggest share of the total energy input in alfalfa production .Such as greenhouse vegetable (Ozkan et al., 2004), cucumber (Mohammadi and Omid, 2010) and apple (Rafiee et al., 2010).

The energy inputs of chemicals and seeds were found to be quite low compared to the other inputs used in production. The average yield of alfalfa was found to be 13510 $kgha^{-1}$ and its energy equivalent was calculated to be 240072.7 $MJha^{-1}$.

Different form and indicators of energy use in producing alfalfa

The energy use efficiency, specific energy, energy productivity, net energy and energy intensiveness of alfalfa production were shown in Table 3. Energy efficiency (energy output-input ratio) in this study was calculated 4.83, showing the affective use of energy in the agroecosystems alfalfa production. Similar results such as 0.64 for cucumber (Mohammadi and Omid, 2010), 2.86 for barely production (Mobtaker et al., 2010), 1.04 for chickpea (Salami and Ahmadi, 2010), 2.12 and 2.05 for organic and nonorganic lentil respectively (Asakereh et al., 2010) have been reported for different crops. Specific energy was 3.68 $MJkg^{-1}$ this means that 3.68 MJ is needed to obtain 1 kg of alfalfa. Energy productivity calculated as 0.27 $KgMJ^{-1}$ in the study area. This means that 0.27 kg of output obtained per unit energy. Net energy was 190383.11 $MJha^{-1}$. This means that the amount of output energy is more than input energy and production in this situation is logical.

Direct, indirect, renewable and non-renewable energy forms used in alfalfa production are also investigated Table 3. The results show that the share of direct input energy was 76.93% in the total energy input compared to 23.07% for the indirect energy. On the other hand, non-renewable and renewable energy contributed to 89.76 and 10.24% of the total energy input, respectively.

Similarly the total energy input consumed for the rainfed wheat crop could be classified as non-renewable (89.76%), direct (76.93%), indirect (23.07%) and renewable energy (10.24%). It is clear that the proportion of non-renewable energy use in surveyed agroecosystems is very high. This result indicates that the agroecosystems

Table 3. Different form and indicators of energy use in alfalfa production systems.

Indicators	Unit	Quantity for alfalfa
Inputs energy	$MJha^{-1}$	49689.59
Output energy	$MJha^{-1}$	240072.7
forage yield	$Kgha^{-1}$	13510
Energy use efficiency		4.83
Specific energy	$MJha^{-1}$	3.68
Energy productivity	$KgMJ^{-1}$	0.27
Net energy	$MJha^{-1}$	190383.11
Directed energy[1]	$MJha^{-1}$	38228.26(76.93%)
Indirected energy[2]	$MJha^{-1}$	11461.33(23.07%)
Renewable energy[3]	$MJha^{-1}$	5087.97(10.24%)
Non-renewable energy[4]	$MJha^{-1}$	44601.62(89.76%)

[1] Includes human labor, diesel, water for irrigation, Electricity. [2]Includes seeds, fertilizers, pesticides, machinery. [3] Includes human labor, seeds, water for irrigation. [4]Includes diesel, pesticides, fertilizers, machinery, Electricity

Table 4. Economic analysis of alfalfa production systems.

Cost and return items	Unit	Value
Yield	$Kgha^{-1}$	13510
Sale price	$\$kg^{-1}$	0.233
Total production costs	$\$ha^{-1}$	889.32
Gross production value	$\$ha^{-1}$	3030.28
Net return	$\$ha^{-1}$	2140.96
Benefit/cost ratio		2.41
Productivity	$Kg\$^{-1}$	15.19

alfalfa production depends on mainly fossil fuels in this region. In fact, today's agricultural production relies heavily on using non-renewable fossil fuels (Refsgaard et al., 1998). Intensity of non-renewable energy consumption resulted from machinery use in production, diesel fuel and fertilizer.

Economical analysis of alfalfa production

An economic analysis of alfalfa production is given in Table 4. According to the table, the total production costs, Gross production value (alfalfa yield multiplied price) and net return were 889.32, 3030.28 and 2140.69 $\$ha^{-1}$ respectively**.** The benefit/cost ratio was 2.41 in the study area which is slightly higher than the benefit-cost ratio of the alfalfa production in Hamadan province (Ghasemi Mobtaker et al., 2010).High benefit to cost ratio shown that costs are less then to net return. Also the productivity (alfalfa yield divided to total production Costs) was 15.19 $kg\$^{-1}$ for the alfalfa production.

Apparently this shows that producing alfalfa is profitable in the study area, also the real net return was high amount in this investigation. The highest shear of total production cost was related to machinery (plant and harvest). Because alfalfa harvested in several times in one year.

Conclusion

In this study the energy indices and cost analysis of alfalfa production in Kermanshah province of Iran have been investigated. The following conclusions are drawn:

1. Total energy input and output in alfalfa production systems were 49689.59 and 240072.7 $MJha^{-1}$.That the highest share, of this amount was reported for diesel fuel, electricity, and nitrogen fertilizer (43.1, 24.3, and 12.2%) respectively.
2. The energy use efficiency, energy productivity, specific energy, net energy of alfalfa production systems were 4.83, 0.27 3.68 and 190383.11 MJ ha^{-1} respectively.
3. The share of total input energy as direct, indirect, renewable and nonrenewable forms were 76.93, 23.07, 10.24 and 89.76%respectively.
4. The benefit-cost ratio, productivity and net return in the alfalfa production were 2.41, 15.19 and 2140.96 $\$ha^{-1}$, respectively.

Finally efficient energy use is key of sustainability in food production systems. Therefore energy management in systems production should be considered an important field in terms of efficient, sustainable and economical use of energy.

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