International Scholars Journals

International Journal of Irrigation and Water Management ISSN 5423-5294 Vol. 6 (1), pp. 001-005, January, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Input–output energy usage for two groups of alfalfa farms with different systems of irrigation

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Accepted 14 April, 2018

The purpose of this study was to determine the amount of input-output energy used in two irrigation systems in baled alfalfa hay production in Hamedan province, Iran, from efficiency of energy consumption point of view. Data were collected from 80 alfalfa farms in August and September 2009. The sample volume was determined by random sampling method. The population investigated was divided in two gropes based on the irrigation system of farms as traditional irrigation system (Group I) and modern irrigation system (Group II). Total energy used in whole production life of alfalfa was 821615.19 MJ/ha in Group I and 723254.38 MJ/ha in Group II. The average inputs energy consumption was maximum for electricity in both gropes of farms. Investigation of energy indices in two gropes of farms showed using of water and energy is in better condition in Group II. In order to reduction of water and electricity consumption, it is suggested that the traditional irrigation systems replaced by modern irrigation systems that have high efficiency.

Key words: Alfalfa, input-output energy, irrigation systems, Iran.

INTRODUCTION

Alfalfa (*Medicago sativa* L.), a perennial legume is used primarily as hay, silage and pasture for animal fodder but also as a source of protein. It is grown in monoculture, in rotation with grain crops and in mixtures with various species of forage grasses and entered into the rotation after winter cereals or before spring crops such as corn or cotton. Alfalfa is sown, managed and harvested for hay production using a variety of cultural practices that greatly influence the energetics of its production. It is established preferably in the autumn or in the spring. During the 4 or 5 years after sowing the crop is harvested two to three times per year in unirrigated areas and five to seven times when irrigated. Various systems are used for irrigation. After harvest the hay is preserved mainly as small to medium rectangular bales (25 to 45 kg per bale) (Tsatsarelis and Koundouras, 1994) . In Hamedan province alfalfa is established in autumn (September and October) and it is harvested three or four times per year (June, July, August and September if it is four time) up to 6 or 7 years after sowing.

Energy use is one of the key indicators for developing more sustainable agricultural practices. Wider use of renewable energy sources increases the energy supply and efficient use can make a valuable contribution to meeting sustainable energy development targets (Streimikiene et al., 2007). Energy use in agriculture has been intensified in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labour-intensive practices or both (Esengun et al., 2007). 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

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resources, and promote sustainable agriculture as an economical production system (Erdal et al., 2007). Efficient energy use in agriculture sector is one of the conditions of sustainable agriculture, because it allows financial savings, fossil resources preservation and decreasing air pollution (Pervanchon et al., 2002). Using energy in agricultural production has been studied for different crops. For example, maize (Phipps et al., 1976), alfalfa (Tsatsarelis and Koundouras, 1994), wheat and sugar beet (Kuesters and Lammel, 1999), soybean (Mandal et al., 2002), cotton (Yilmaz et al., 2005), tomato (Esengun et al., 2007), potato (Mohamadi et al., 2008), cherries (Kizilaslan, 2009), cucumber (Mohammadi and Omid, 2010).

Irrigation is important operations in agriculture and efficient use of water is one of the most importance goals of modern agriculture. In a study which was done previously by the authors on energy consumption in alfalfa production, the electricity used in irrigation system was the highest energy inputs. This input consumes about 76% of total energy inputs in alfalfa production. Being water placed in sub levels and using ancient methods in irrigation were reported the reasons of high consumption of electrical energy in the studied region which leads to higher consumption of both water and energy (Mobtaker et al., 2010a). Thus, the present study was aimed to determine the input–output energy usage for two groups of alfalfa farms with different systems of irrigation in the aforementioned case study carried out by Mobtaker et al. (2010a) from the point of view of energy consumption efficiency. It is worthwhile mentioning that the data used in the present study are those used in the previously mentioned study.

MATERIALS AND METHODS

The study was performed in central region of Hamedan province which is located in the west of Iran; within 33° 59 and 35° 48 north latitude and 47° 34 and 49° 36 east longitude. Hamedan region has an area of 1,949,400 ha; and the farming area, with a share of 51.7%, is 1,008,038 ha. The data were collected from 80 alfalfa farms using a face to face questionnaire in August and September 2009. The simple random sampling method was used to determine survey volume as (Kizilaslan, 2009; Mobtaker et al., 2010b):

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

where n is the required sample size; s, the standard deviation; t, the t value at 95% confidence limit (1.96); N, the number of holding in target population and d, the acceptable error (permissible error 5%). consequently calculated sample size in this study was 68, but it was considered to be 80 to ensure the accuracy.

The inputs used in the production of alfalfa were specified in order to calculate the energy equivalences in the study. Inputs in alfalfa production were: human labour, machinery, diesel oil, chemical fertilizers, farmyard manure, biocides, water for irrigation, and electricity and output was alfalfa weight. The previous study was used to determine the energy equivalents' coefficients (Mobtaker et al., 2010a). Direct energy of irrigation was calculated by following equation (Kitani, 1999):

$$DE = \frac{\delta \times g \times H \times Q}{\eta_1 \times \eta_0} \qquad (2)$$

Where DE is direct used energy (J/ha), is water density, g is gravity, H is total dynamic head, Q is the overall rate of water (m3/ha), 1 is the pump efficiency, and 0 is the overall efficiency of the power device.

The population investigated was divided in two groups based on the irrigation system of farms as traditional irrigation system (Group I) and modern irrigation system (wheel move) (Group II). Since the studied area climate is considered to be semi -arid, almost total water demands of the alfalfa (approximately 13500 m^3/yr) is supplied by irrigation. Besides, due to the high costs of the modern irrigation systems, a small percentage of the farmers as 15% use this system. The input and output were calculated per hectare and then, these input and output data were multiplied by the coefficient of energy equivalent. Based on the energy equivalents of the inputs and output, the energy indices were calculated (Mandal et al., 2002; Mohammadi et al., 2008; Khan et al., 2009). These indices showed in Table 1.

RESULTS AND DISCUSSION

Table 2 shows the inputs used and output of alfalfa production in Group I and Group II, in the area of survey. Also Figure 1 shows the energy use pattern in two groups of farms. The results indicate 580.97 and 538.43 h of human power and 251.68 and 274.53 h of machine power are required per hectare of alfalfa production in Group I and Group II, respectively. Total energy used in whole production life of alfalfa was 821615.19 MJ/ha in Group I and 723254.38 MJ/ha in Group II. The average inputs energy consumption was maximum for electricity in both gropes which accounted to be about 77 and 68% of the total energy input in Group I and Group II, respectively. These results can be compared with Tsatsarelis and Koundouras (1994), who reported electricity consumption for alfalfa production, has the biggest part of the total energy input (41.73%). Average yield in Group I and Group II farms were 96837.14 and 94400.00 kg/ha, respectively. Chemical fertilizers (mainly Nitrogen) are second energy consuming in alfalfa production and consume 100817.81 and 127799.58 MJ/ha in Group I and Group II, respectively. Human labour were the least demanding energy input for alfalfa production with 1138.71 and 1055.32 MJ/ha in the first and second groups of farms. The similar results were reported in literature which shows that energy input of human labour has minimum part of the total energy input in agricultural crops production (Sartori et al., 2005; Kizilaslan, 2009).

The results showed using modern irrigation system, the energy inputs in alfalfa production can be decreased by about 12%. Also the electricity and the water use can be

Table 1. Indices of water and energy in Agriculture production.

Indicator	Definition	Unit	
Energy use efficiency	$\frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}}$	ratio	(3)
Energy productivity	$\frac{\text{Alfalfa output (kg/ha)}}{\text{Energy input (MJ/ha)}}$	kg/MJ	(4)
Specific energy	$\frac{\text{Energy input (MJ/ha)}}{\text{Energy output (MJ/ha)}}$	MJ/kg	(5)
Net energy gain	Energy output (MJ/ha) – Energy input (MJ/ha)	MJ/ha	(6)
Water productivity	$\frac{\text{Alfalfa output (kg/ha)}}{\text{Water applied (m}^3\text{/ha)}}$	kg/m3	(7)
Water and energy productivity	$\frac{\text{Alfalfa output (kg/ha)}}{\text{Water applied (m}^3\text{/ha)} * \text{Energy input (MJ/ha)}}$	kg/m3 MJ	(8)

Table 2. Amounts of inputs and output and their equivalent energy.

Inputs	Unit	Group I		Group II	
		Quantity per hectare	Energy equivalent (MJ/ha)	Quantity per hectare	Energy equivalent (MJ/ha)
A. Input					
1. Human labour	h	580.97	1138.71	538.43	1055.32
2. Machinery	h	251.68	16308.68	274.53	17789.54
3. Diesel fuel	L	1130.60	63664.09	1241.50	69908.86
4. Chemical fertilizers	kg	2957.45	100817.81	2326.80	127799.58
(a) Nitrogen	kg	1216.80	80479.62	1857.60	122861.66
(b) Phosphate (P_2O_5)	kg	1733.69	21567.14	469.20	5836.85
(c) Potassium (K_2O)	kg	6.96	77.57	0.00	0.00
5. Farmyard manure	kg	11457.13	3437.14	22000	6600.00
6. Biocide	kg	17.32	2077.88	23.10	2772.00
7. Electricity	kWh	52924.98	631395.00	41509.43	495207.53
8. Seed	kg	98.79	2775.88	75.50	2121.55
The total energy input	MJ		821615.19		723254.38
B. Output					
1. baled alfalfa hay	kg	96837.14	1530026.86	94400.00	1491520.00
Total energy output (MJ)	MJ		1530026.86		1491520.00

decreased by about 22 and 26% respectively. This mean using modern irrigation system, per each tone of alfalfa produced 106.82 kWh of electricity and 822.92 MJ of energy can be saved. High efficiency of modern methods of irrigation is among the reason of saving of water and electrical energy. The results of analysis of water and energy indices in alfalfa production for two groups of farms are illustrated in Table 3. Also total mean energy input as direct, indirect, renewable and non-renewable forms are given. The energy use efficiency in Group I was calculated as 1.82 and in Group II as 2.06, respectively. Tsatsarelis and Koundouras (1994) conclu-ded that energy use efficiency in alfalfa production to be 6.25 in northern Greece. In the literature, which previously

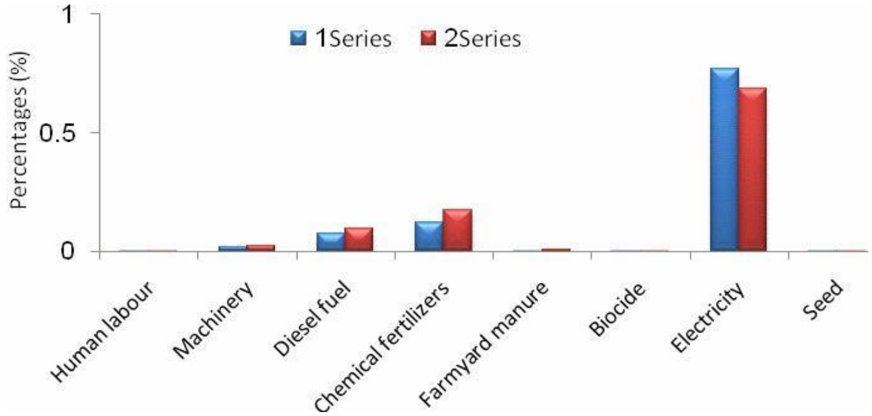

Figure 1. Energy use pattern in two gropes of farms.

Table 3. Analysis of water and energy indices in alfalfa production.

Variables	Unit	Group I	Group II
Energy use efficiency	ratio	1.82	2.06
Energy productivity	kg/MJ	0.117	0.130
Specific energy	MJ/kg	8.48	7.67
Net energy gain	MJ/ha	708411.13	768265.62
Water used	M3/ha	98906.50	73390.32
Water productivity	kg/m3	0.979	1.286
Water and energy productivity	g/m3 MJ	0.0012	0.0018
Direct energy [a]	MJ/ha	696197.80	566171.71
Indirect energy [b]	MJ/ha	125417.40	157082.67
Renewable energy [c]	MJ/ha	7351.74	9776.87
Non-renewable energy [d]	MJ/ha	814263.46	713477.51

[a] Includes human labour, diesel fuel, electricity; [b] Includes seeds, chemical fertilizers, farmyard manure, biocides, machinery; [c] Includes human labour, seeds, farmyard manure; [d] Includes diesel fuel, electricity, biocides, chemical fertilizers, machinery.

made for some other crops, the energy input–output ratio were calculated as 2.8 for wheat, 4.8 for cotton, 3.8 for maize, 1.5 for sesame (Canakci et al., 2005), 0.74 for cotton (Yilmaz et al., 2005), 1.25 for potato (Mohammadi et al., 2008) and 0.64 for greenhouse cucumber (Mohammadi and Omid, 2010) . The average energy productivity of Group I was 0.117 kg/MJ, while in Group II it was 0.130 kg/MJ. The net energy gain in Group I and Group II was 708411.13 MJ/ha and 768265.62 MJ/ha, respectively. Investigation of energy indices in two gropes of farms showed using of water and energy is in better condition in Group II.

The water productivity of alfalfa in Group I was calculated as 0.979 kg/m^3 and in Group II as 1.286 kg/m^3, respectively. This means that 0.979 and 1.286 kg of alfalfa yield was obtained per unit of water (m^3). Khan et al. (2009) reported water productivity as 0.56 kg/m^3 for rice, 1.71 kg/m^3 for wheat and 3.27 kg/m^3 for barley. The water and energy productivity in Group I and Group II was 0.0012 and 0.0018 g/m^{3}MJ, respectively. The water and energy productivity is amount of yield per unit of energy and water inputs. It captures the combined effect of water and energy inputs on yield (Khan et al., 2009). Thus Group II seems more efficient in terms of energy and water use jointly. The rate of direct energy was greater than that of indirect energy in both groups. It was found that the direct and indirect energy inputs were 696197.80 and 125417.40 MJ/ha in Group I and 566171.71 and 157082.67 MJ/ha in Group II, respectively. Also the renewable and non- renewable energy inputs were 7351.74 and 814263.46 MJ/ha in Group I and 9776.87 and 713477.51 MJ/ha in Group II, respectively. Similar results reported that the ratio of direct energy is higher than that of indirect energy, and the rate of non-renewable energy is higher than that of renewablen energy consumption (Mohammadi et al., 2008; Kizilaslan, 2009).

Conclusion

In this study, the level of energy consumption for input and output energies in two irrigation systems in baled alfalfa hay production was investigated in Hamedan province of Iran. Based on the results of the investigations, the following conclusions were drawn:

1. Total energy used in whole production life of alfalfa was 821615.19 MJ/ha in Group I and 723254.38 MJ/ha in Group II.
2. The average inputs energy consumption was maximum for electricity in both gropes which accounted to be about 77 and 68% of the total energy input in Group I and Group II, respectively.
3. The energy use efficiency and water productivity in Group I were calculated as 1.82 and 0.979 kg/m^3 and in Group II as 2.06 and 1.276 kg/m^3 respectively.
4. The results showed using modern irrigation system, the energy inputs, the electricity and the water use in alfalfa production can be decreased by about 12, 22 and 26% respectively.
5. It is strongly suggested that the irrigation systems efficiency is raised or traditional irrigation system is replaced with modern irrigation system.

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