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Energy Efficiency in Alfalfa (*Medicago sativa* L.) Production System in North West of Iran (Case Study: Mahabad City)

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ABSTRACT

In order to evaluate energy efficiency in alfalfa production system was investigated by questionnaire of farmers in different farms in West Azerbaijan, Mahabad, Iran during 2005 to 2010 growing seasons. Energy efficiency was calculated by using of consumed data as inputs, total production as output, and their concern equivalent energy. The amount of energy and inputs used in the farms in 2005 was more than the next years and the highest energy production (output) and energy efficiency (output to input ratio) was obtained from the 2008, 2009 and 2010. Our results showed that, the highest energy consumption in the studied fields was due to irrigation, machinery and nitrogen fertilizer, respectively. Also, lowest value was related to planting and labor, respectively. Using new irrigation methods, such as sprinkler and drip irrigation, with using of combination machines, doing timely required temporal of tractor services and suitable management of cropping system such as representing a fit crop rotation and benefiting from legumes for biological nitrogen fixation, can reduce energy consumption in production.

Key words: consumption, energy production, input, management, output.

INTRODUCTION

Goal of sustainable agriculture is to use energy more efficiently in crop production. Energy use is one of the key indicators for developing more sustainable agricultural practices and also is principal requirements for sustainable agriculture (8). Also, the use of energy flow is method of estimating agricultural development and permanent production in agricultural areas, and this is one of the most important subjects in agricultural ecology. In different parts of the world, the energy input to output ratio is calculated in different agricultural ecosystems (15, 4).

Actually, energy consumption in the agricultural sector can be divided into many different ways. In a kind of division, energy consumption in the agriculture sector can be three groups of physical energy (physical and human resources, machinery, electricity and oil consumption) of chemical (chemical fertilizers and pesticides) and seed energy (energy stored in the biochemistry of seed) was divided (10).

On the other hand, forage crops which directly or indirectly consumes by cattle and poultries, play tremendous important roles in animal production (1). Growing legumes offers the opportunity to add N to the soil system biologically which reduces fossil fuel costs associated with mineral fertilizer (3).

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. This plant as a legume forage crop produces high net energy yield. The energy required for production in this forage crop is far lower than the total energy contained in the crop. This is due to biological nitrogen fixation. In addition, alfalfa's ability to fix atmospheric nitrogen makes it valuable both for crop rotation and for a more sustainable and environmentally safe agriculture (18).

Many studies conducted in different ecosystems, in order to evaluate the energy efficiency (output to input ratio) of crops have been conducted (9). During recent years, around the world was performed many efforts to measure and estimate the energy consumption in production of agricultural products. Peterson et al. (12) reported that, increasing the energy efficiency in nitrogen consumption depending on the type of previous product and amount of soil mineral nitrogen. In their study the maximum energy efficiency was 1.6 for rotation with corn, soybean and wheat, but this amount was 4.7 in monocropping of corn. Streimikiene et al. (16) demonstrated that, energy use in agricultural production has become more intensive due to the use of fossil fuel chemical fertilizers, pesticides, machinery and electricity to provide sub-stantial increases in food production.

According to the researchers, by knowing the amount of nitrogen available obtained from product remains of previous year and the principal crop's planting date, can be improved the energy efficiency and increase the economic incomes. Also can be reduced the environmental pressures due to nitrate increase, nitrogen leaching, ground water pollution and production of greenhouse gases in the atmosphere. Golinejad and Hassanzadeh (5) estimated that, energy consumption of dryland wheat farms in the Mazandaran Province was 5359000 kcal ha^{-1} and energy efficiency was 0.42 in this crop. Valdiani et al. (17) evaluated energy balance in seed multiplication farm on dryland wheat cultivars, and reported that, energy consumption was 649900 kcal for this product. Several researchers mentioned that, energy inputs consumption was variable and depends on amount of nitrogen consumption and the type of crop (6, 11). Can be concluded that evaluation of energy balance and calculation of energy efficiency and identify the types and amounts of energy, can be a scientific method for measuring amount of stability and stability produced in an agricultural ecosystem (15).

therefore, the objective of present study was to evaluate the alfalfa production energy efficiency in North West of Iran (West Azerbaijan, Mahabad) and study the affective factors for reduce the efficiency of farms.

Table I. Labor and required machinery in different agricultural operations for alfalfa production in Mahabad city (2005-2010) (Direct energy input)

Type of operation	Duration of operation (H ha^{-1})	Fuel consumption (L ha^{-1})	energy input (Kcal ha^{-1})
	2005		
Tillage	4	56	641088
Disc	1.5	21	240408
Fertilizer spreader	0.5	7	80136
Land grading	2	28	320544
Planting (land spreader)	2	-	350
Irrigation	40	658.4	7537362.4
Harvest	3	42	480816
Rake	2	28	320544
Packing	3	42	480816
Transport	3	42	480816
Labor	160	-	28000
Total	-	-	10610880
	2006 and 2007		
Fertilizer spreader	2	28	320544
Irrigation	80	1316.8	74724
Harvest	8	112	1282176
Rake	4.5	63	721224
Packing	5	70	801360
Transport	4	56	641088
Labor	170	-	29750
Total	-	-	18870866
	2008, 2009 and 2010		
Fertilizer spreader	3	42	480816
Irrigation	120	1975.2	22612088
Harvest	12	168	1923264
Rake	6.5	91	1041768
Packing	7	98	1121904
Transport	5.5	77	881496
Labor	230	-	40250
Total	-	-	28101586

MATERIALS AND METHODS

This study was conducted to evaluate energy efficiency in alfalfa production system during 2005 to 2010 growing seasons at West Azerbaijan, Mahabad, Iran, (45°43'3"E longitude and 36°46'3"N latitude). This region has an area of 2591 km^{-2} and weather condition is cold and semiarid. In this study, energy balance in alfalfa fields was evaluated by statistics and information derived with questionnaires from farmers. The information received from farmers, including labor and necessary machinery from planting to harvesting stage is presented in Table I. Then the amount of the each factors and inputs per hectare, without using a specific formula, is presented in Table II. In this study, information about type of operation and resources energy in 2006 by 2007, as well as 2008 and 2009 by 2010 were similar, that information about this presented in Table I and II.

If the amount of energy entered into the farm by electric for irrigation to collect with total energy, the total amount of energy input in 2005 is 4885187 kcal ha^{-1}, in 2006 and 2007 will be 8072544 kcal ha^{-1} and in 2008, 2009 and 2010 is 10097697 kcal ha^{-1}. Then the amount of energy efficiency of the alfalfa fields has been evaluated by the energy ratio (output to input) (5, 7):

$$\text{Energy efficiency} = \frac{\text{Energy input}}{\text{Energy output}}$$

Table II. Energy inputs consumed on alfalfa fields in Mahabad city (2005-2010) (Indirect energy input)

Energy resources	Consumption (Kg ha^{-1})	Energy input for each kilogram (Kcal)	Energy input (Kcal ha^{-1})
2005			
Nitrogen fertilizer	100	17600	1760000
Phosphorous fertilizer	200	3190	638000
Sterilized seeds	50	4200	210000
Machinery	85	20712	1760520
Total	-	-	4368520
2006 and 2007			
Nitrogen fertilizer	250	17600	4400000
Phosphorous fertilizer	150	3190	478500
Herbicide	0.2	-	19982
Pesticides	0.8	-	69528
Machinery	100	20712	2071200
Total	-	-	7039201
2008, 2009 and 2010			
Nitrogen fertilizer	300	17600	5280000
Phosphorous fertilizer	200	3190	638000
Herbicide	74	-	39964
Pesticides	0.12	-	104292
Machinery	120	20712	2485440
Total	-	-	8547696

RESULTS AND DISCUSSION

According to collected data, energy production (output) in alfalfa fields was shown in Table III. Amount of the forage energy production was measured by using bomb calorimeter. Investigations showed that from 100 kg of alfalfa forage, produced around 20 kg of hay or 3.6 kg of protein. Therefore the amount of protein production in a hectare, in 2005 was 1080 kg ha^{-1}, in 2006 and 2007 was 3240 kg ha^{-1} and in 2008, 2009 and 2010 was 5400 kg ha^{-1}. The amount of energy input for each of the factors in farms is provided in Table I and II. According to the results the maximum energy input for alfalfa fields, is related to irrigation, machinery and nitrogen fertilizer consumption, and the minimum energy input is related to alfalfa planting and labor. In this study, the amount of energy efficiency (output to input ratio) in alfalfa fields calculated over years, in 2005 was 3, in 2006 and 2007 was 6, as well as in 2008, 2009 and 2010 was 7 (Table IV).

According to the information that presented in Table III, energy output increased from the second year onwards, because some of the direct energy consumption (input) including the tillage, disc, land grading, planting and some of the indirect energy consumption (input) including the use of sterilized seeds is removed from the second year onwards in alfalfa fields. This process increased the energy efficiency in the next years. The percentage of direct and indirect energy consumption of each input in these farms are presented in figure I and II. According to the figures, the highest percentage of energy input was related to irrigation, machinery and nitrogen fertilizer. Reduction of precipitation in recent years increased the Irrigation frequency. This matter reduced the energy efficiency, because the water is very important factor in energy consumption (12). With increasing water and nitrogen fertilizer, can be increased seed production energy and biomass in many products, and increased production with increasing consumption of fossil fuels is possible (2). According to the fertilizer recommendations based on soil tests, can understand that, excessive consumption of nitrogen fertilizers, increasingly reduce the yield. Pimental et al. (13)

announced that the most important criterion for fertilizer recommendations for each area is soil sampling; determine the physical and chemical properties and soil fertility levels.

Table III. Energy production on alfalfa fields in Mahabad city (2005-2010)

Type of energy production (Kg)	The amount of energy per unit ($Kcal.kg^{-1}$)	Fresh weight of forage ($Kg.ha^{-1}$)	Amount of energy production ($Kcal.ha^{-1}$)
	2005		
Forage (stems, leaves and flowers)	1771	30000	53130000
	2006 and 2007		
Forage (stems, leaves and flowers)	1771	90000	159390000
	2008, 2009 and 2010		
Forage (stems, leaves and flowers)	1771	150000	265650000

Table IV. Energy balance on alfalfa fields in Mahabad city

Production (forage)	Energy input (direct + indirect)	Energy output	Energy efficiency
2005	15496067	53130000	3
2006 and 2007	26943410	159390000	6
2008, 2009 and 2010	38199283	265650000	7

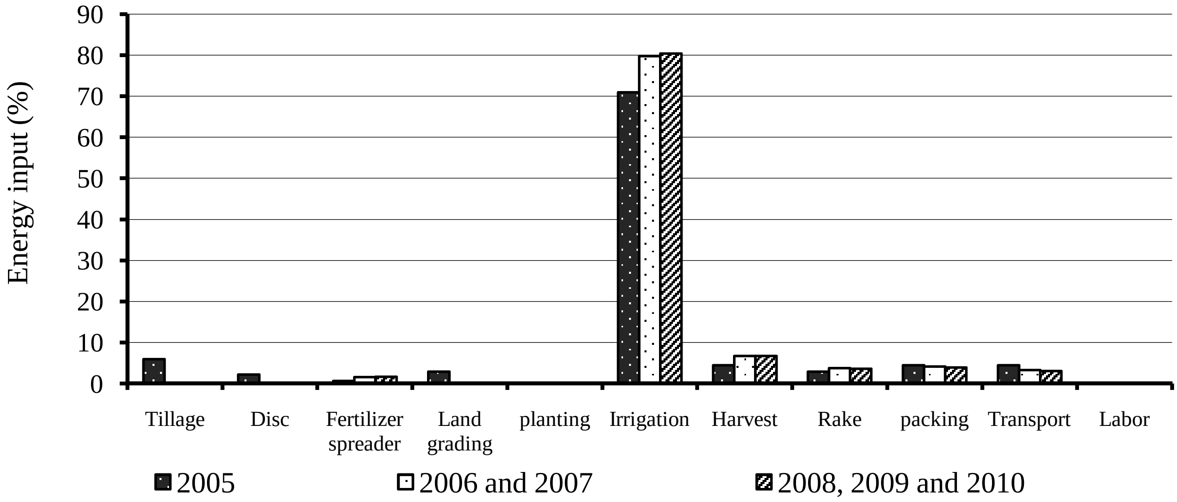

Figure I. The percent of energy input (directly) of each of the factors on alfalfa fields in Mahabad city (2005-2010)

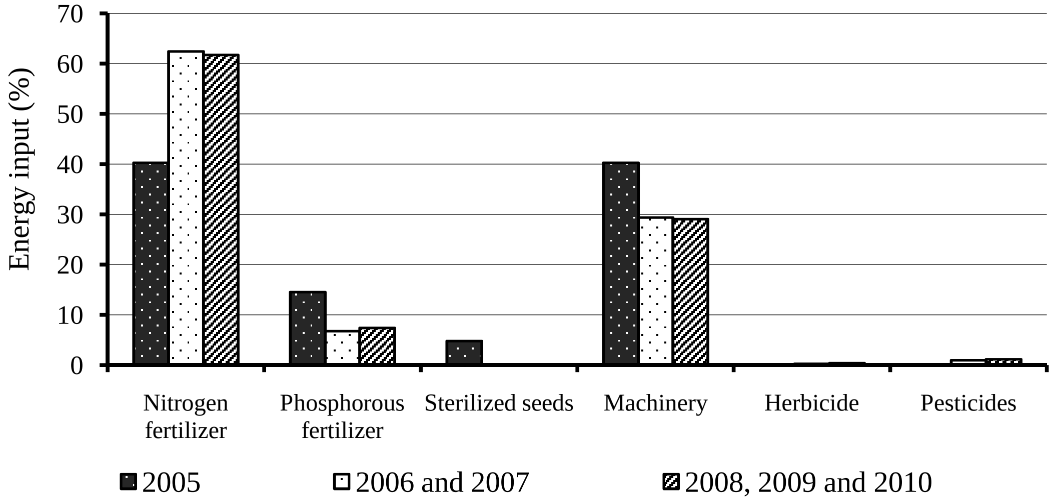

Figure II. The percent of energy input (indirectly) of each of the factors on alfalfa fields in Mahabad city (2005-2010)

According to the mentioned and calculated of energy consumption for each of the factors and inputs in production of alfalfa, can suggested some solutions to reduce energy consumption, such as in relation about irrigation, machinery and nitrogen fertilizer in alfalfa fields. Can be recommended some of the strategies, like using new methods of irrigation such as sprinkler and drip irrigation, according to the proper time of irrigation, the use of super-absorbent compounds and using organic fertilizer in order to preserve the water and soil. As mentioned earlier, after irrigation, machinery allocated to itself the highest share of energy consumption. So can be recommended that the use of multifunction machines to reduce duration and number of operations of machines. Also perform regular maintenance and required services in tractors can reduce the fuel consumption. Since the excessive use of chemical fertilizers, in addition to energy higher consumption, the cause of soil erosion, contamination of surface and ground water, as well as loss of valuable soil organic matter is very harmful (14). Sampling and analysis tests of soils and observance of proper crop rotation; can also be an effective step to reduce nitrogen fertilizer consumption. Thus, is recommended that further studies in relation to present the best crop rotation system in the region. So growing more alfalfa for biofuel production would contribute to making the many countries energy independent, improving natural soil resource, reducing greenhouse gas emissions, and protecting water quality.

CONCLUSION

Application correct management including the using new irrigation methods, suitable agricultural machinery and time as well as proper use of inputs; can reduce the energy consumption. Thus, increased crop yield per unit area and will improve energy use efficiency.

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