INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH
Hassan Ghasemi Mobtaker , Vol.2, No.1, 2012

Non–renewable Energy Inputs–yield Relationship of Alfalfa Production in Iran

Hassan Ghasemi Mobtaker*

*Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

‡ Corresponding Author; Hassan Ghasemi Mobtaker, (+98)2612801011,mr.mobtaker@yahoo.com

Received: 28.11.2011 Accepted:31.12.2011

Abstract- The purpose of this study was to determine the amount of non-renewable inputs energy used in baled alfalfa hay production in Hamedan province, Iran. Data were collected from 80 alfalfa farms in August and September 2009. The sample volume was determined using random sampling method. Total non-renewable energy inputs for alfalfa production were calculated to be 802920.13 MJ ha-1 which accounted to be about 99.05% of the total energy input. Econometric model evaluation showed that machinery energy was the most significant input which affects the output level. Sensitivity analysis results indicates that with an additional use of 1 MJ of each of the machinery and diesel fuel energy would result in increase in yield by 3.918 and 0.357 kg, respectively. The MPP of biocides was negative. It can be because of applying the input more than required or improperly applying. This energy use pattern in the Persian agriculture can create some environmental problems such as increase in global warming, CO2 emissions, and non-sustainability. Thus, policy makers should undertake new policy tools to ensure sustainability and efficient energy use.

Keywords- Alfalfa, Non–renewable energy inputs, Cobb–Douglas, Sensitivity of energy

1. Introduction

Alfalfa (Medicago sativa L.) is a flowering plant in the pea family, cultivated widely throughout the world as forage for cattle, and is most often harvested as hay, but can also be made into silage, grazed, or fed as green chop. It is the most productive legume for Hamedan province, with potential yields exceeding twelve tons of hay per ha/yr. 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 [1]. 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 [2].

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 resources, and promote sustainable agriculture as an economical production system [3]. 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 [4]. Modern farming has become very energy intensive; therefore there is a great need to balance the use and availability of energy [5].

Production functions are central to the determination of the efficient allocation of resources. Many researchers have studied energy analysis and relationship between inputs and yield to determine the energy efficiency of plant production [6-9].

In a study which was done previously by the author on energy consumption in alfalfa production, the non-renewable energy has high share in inputs energy. The rate of non-renewable energy was determined as 99.05% of total energy input [10]. The aim of this study was to determine the relationship between non-renewable energy inputs and energy output of alfalfa production in Iran. Also Sensitivity analysis of energy inputs for alfalfa crop production was investigated and the Marginal Physical Product technique was utilized to analyze the sensitivity of energy inputs on alfalfa yield.

2. 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 [11]. 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 below [8, 12]:

$$n = [N(S \times t)^2]/[(N-1)d^2 + (S \times t)^2] \quad (1)$$

Consequently calculated sample size in this study was 68, but it was considered to be 80 to ensure the accuracy. The non-renewable energy inputs used in the production of alfalfa were specified in order to calculate the energy equivalences in the study. Non-renewable energy inputs in alfalfa production were: machinery, diesel fuel, chemical fertilizers, biocides and electricity and output was alfalfa weight. For calculate the energy of input the units in Table 1 were used.

In order to obtain a relationship between non-renewable energy inputs and yield, a mathematical function needs to be specified. For this purpose, Cobb-Douglas production function was selected since it produced better results (yielded better estimates in terms of statistical significance and expected signs of parameters). This function has been used by several authors to examine the relationship between energy inputs and yield [5, 6, 7, 8, 13].

Table 1. Energy equivalent of non–renewable inputs and output in agricultural production

Inputs (unit)	**Unit**	**Energy equivalent (MJ unit^{-1})**	**Reference**
A. Inputs			
1. Machinery	h	64.80	[14]
2. Diesel fuel	l	56.31	[14]
3. Chemical fertilizers			
(a) Nitrogen	kg	66.14	[15]
(b) Phosphate (P_2O_5)	kg	12.44	[15]
(c) Potassium (K_2O)	kg	11.15	[15]
4. Biocide	kg	120	[14, 16]
5. Electricity	kWh	11.93*	[13, 17]
B. Output			
1. Dry hay (15% w.b.)	kg	15.8	[18]

* This coefficient used according to the efficiency of power plants and power loss of distribution networks reported in references for Iran.

The Cobb-Douglas production function is expressed as:

$$Y = f(x)\exp(u) \quad (2)$$

Equation (2) can be further re-written as:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad i = 1, 2, 3, \ldots, n \quad (3)$$

where Y_i denotes the yield of the i_{th} farmer; X_{ij}, the vector of inputs used in the production process; a, the constant term; α_j, represent coefficients of inputs which are estimated from the model and ei, the error term.

Assuming that when the energy input is zero, the crop production is also zero; Eq. (3) reduces to [9, 19, 20]:

$$\ln Y_i = \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad (4)$$

In the present case, we have n = 5; therefore the Eq. (4) can be expressed in the following form:

$$\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + e_i \quad (5)$$

where X_i stand for corresponding energies as X_1, machinery; X_2, diesel fuel; X_3, chemical fertilizers; X_4, biocides; and X_5, electricity.

Eqs. (5)-(7) were estimated using ordinary least square technique.

The Marginal Physical Product (MPP) technique, based on the response coefficients of the inputs, was utilized to analyze the sensitivity of energy inputs on alfalfa yield. The MPP of a factor indicates the change in the output with a unit change in the factor input in question, keeping all other factors constant at their geometric mean level. Assuming that no other inputs to production change, the MPP of the various inputs was computed using the αj of the various energy inputs as [6]:

$$MPP_{xj} = [GM(Y)/GM(X_j)] \times a_j \quad (6)$$

where MPP_{xj} is marginal physical productivity of jth input; αj, regression coefficient of jth input; GM(Y), geometric mean of yield; and GM(X_j), geometric mean of j_{th} input energy on per hectare basis.

In production, returns to scale refer to changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). In the Cobb-Douglas production function, it is indicated by the sum of the elasticities derived in the form of regression coefficients [8, 9].

The greenhouse gas (GHG) emissions were beyond the scope of this analysis and the corresponding amount was calculated. The diesel fuel combustion can be expressed as fossil CO2 emissions with equivalent of 2764.2 g L^{-1}. Also, the machinery and fertilizer supply terms can be expressed in terms of the fossil energy required to manufacture and transport them to the farm with CO_2 equivalents of 0.071 Tg PJ^{-1} and 0.0058 Tg PJ^{-1} for machinery and chemical fertilizers, respectively [21].

3. Result and Discussion

The ratio of non-renewable energy inputs used in alfalfa production is showed in Fig. 1. Total non-renewable energy inputs for alfalfa production were calculated to be 802920.13 MJ ha-1 which accounted to be about 99.05% of the total energy input. Electricity Consumes 75.79% (614371.50 MJ ha-1) of total energy inputs followed by chemical fertilizers 13.01% (105445.58 MJ ha^{-1}) during production period. Electricity consumption in alfalfa production is for irrigation purposes. Having deep wells in the region and not using modern efficient irrigation methods are among the reasons of high consumption of electrical energy in the studied region. In order to reduce the electricity consumption, using of modern methods of irrigation with high efficiency which leads in saving water consumption can be suggested.

Regression results for Eq. (5) are shown in Table 2. For data used in this study, autocorrelation was tested using Durbin-Watson method [7, 13]. The Durbin-Watson value was found to be 1.871 for Eq. (5) which indicates that there was no autocorrelation at the 5% significance level in the estimated model. The R^2 value was determined as 0.988 for this Eq., implying that around 0.988 of the variability in the energy inputs was explained by this model.

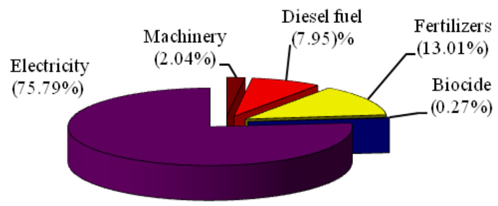

Fig. 1. Distribution of non-renewable energy inputs energy in alfalfa production.

Results of assessment of Cobb-Douglass function on each one of the non-renewable energy inputs in alfalfa production indicates that the impact of each one of the inputs differ in constitution of output energy. Machinery had the highest impact (0.673) among other inputs and significantly contributed on the productivity at 1% level. It indicates that a 1% increase in the energy machinery input led to 0.875% increase in yield in these circumstances. The second important input was found as diesel fuel with 0.238 elasticity followed by electricity with 0.084 elasticity.

Hatirli et al. [20] developed an econometric model for greenhouse tomato production in Antalya province of Turkey and reported that human labour, chemical fertilizers, biocides, machinery and water energy were important inputs significantly contributed to yield. Human labour, farmyard manure and biocides had a negative impact on alfalfa yield.

Table 2. Econometric estimation results of non–renewable inputs

Endogenous variable: yield **Exogenous variables**	**Coefficient**	***t*–ratio**	**MPP**
Model 1: $\ln Y_i = \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + e_i$			
Machinery	0.673	8.496*	3.918
Diesel fuel	0.238	3.157*	0.357
Chemical fertilizers	0.015	0.995	0.017
Biocides	–0.010	–4.370*	–2.196
Electricity	0.084	3.030*	0.015
Durbin–Watson	1.871		
R^2	0.988		
Return to scale ($\sum_{i=1}^{n} \alpha_i$)	1.000		

* Indicates significance at 1% level.

The sensitivity of non-renewable energy inputs was analyzed using the marginal physical productivity method and partial regression coefficients on output level and the results are provided in Table 2. As shown, the major MPP was drown for machinery energy (3.918), followed by diesel fuel energy (0.357). This indicates that with an additional utilize of 1 MJ of each of the machinery and diesel fuel energy would result in increase in yield by 3.918 and 0.357 kg, respectively. As a consequence, parameters with a large sensitivity coefficient have a strong influence on the state variable. This identifies which factors should be identified and measured most carefully to assess the state of the environmental system, and which environmental factors should be managed preferentially [22].

The MPP of biocides energy was found to be -2.196. A negative value of MPP of input implies that additional units of inputs are contributing negatively to production, i.e. less production with more input. The sum of the regression coefficients of non-renewable energy inputs was calculated as 1.000 for Eq. (5). This implied that a 1% increase in the total non-renewable energy inputs utilize would lead in 1.000% increase in the alfalfa yield for this Eq.

Table 3. Greenhouse emission in alfalfa production

Input	Consumption (MJ)	Equivalent(Tg (CO_2) PJ^{-1})	Amount of CO_2 (ton)	Percentage
Diesel fuel	64444.54	0.0578	3724894	67.6
Machinery	16493.54	0.071	1171041	21.3
Fertilizers	105445.58	0.0058	611584	11.1
Total	186383.66	–	5507519	100

Results indicated that alfalfa production is mostly depending on fossil energy sources. As it can be seen in Table 3, the total amount of CO2 was calculated as 5507519 tones. Diesel fuel had the highest share (67.6%) followed by manufacturing machinery (21.3%) and manufacturing chemical fertilizers (11.1%). Using ethanol and biodiesel as biofuel is essential in the 21st century to reduce the high GHG emissions. Field operations with minimum machinery use (especially tillage operation) and machinery production are needed to be considered to reduce the amount of CO2 [21].

4. Conclusion

In this study, the level of non-renewable energy consumption in baled alfalfa hay production was investigated in Hamedan province of Iran. Also sensitivity analysis of non-renewable energy input level on alfalfa yield was investigated. Based on the results of the investigations, the following conclusions were drawn:

1. Total non-renewable energy inputs for alfalfa production were calculated to be 802920.13 MJ ha-1 which accounted to be about 99.05% of the total energy input.

2. The average inputs energy consumption was maximum for electricity which accounted to be about 76% of the total energy input. Having deep wells in the region and not using modern efficient irrigation methods are among the reasons of high consumption of electrical energy in the studied region.

3. Machinery had the highest impact (0.673) among other inputs and significantly contributed on the productivity at 1% level. It indicates that a 1% increase in the energy machinery input led to 0.875% increase in yield in these circumstances.

4. The MPP of biocides energy was found to be -2.196. This that additional units of inputs are contributing negatively to production, i.e. less production with more input.

5. The total amount of CO2 was calculated as 5507519 tones and diesel fuel had the highest share (67.6%).

References

[1] D. Streimikiene, V. Klevas, J. Bubeliene, “Use of EU structural funds for sustainable energy development in new EU member states”, Renew. Sust. Energ. Rev. England, vol. 11, pp. 1167-1187, 2007.

[2] K. Esengun, O. Gunduz, G. Erdal, “Input-output energy analysis in dry apricot production of Turkey”, Energy Convers. Manage. England, vol. 48, pp. 592-598, 2007.

[3] G. Erdal, K. Esengun, H. Erdal, O. Gunduz, Energy use and economical analysis of sugar beet production in Tokat province of Turkey”, Energy England, vol. 32, pp. 35-41, 2007.

[4] F. Pervanchon, C. Bockstaller, P. Girardin, “Assessment of energy use in arable farming systems by means of an agroecological indicator: the energy indicator”, Agric. Syst. vol. 72, pp.149-172, 2002.

[5] S. Singh, S. Singh, C.J.S. Pannu, J. Singh, “Optimization of energy input for raising cotton crop in Punjab”, Energy Convers. Manage. England, vol 41, pp. 1851-1861, 2000.

[6] G. Singh, S. Singh, J. Singh, “Optimization of energy inputs for wheat crop in Punjab”, Energy Convers. Manage. England, vol. 45, pp. 453-465, 2004.

[7] A. Mohammadi, M. Omid, “Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran”, Appl. Energy England, vol. 87, pp. 191-196, 2010.

[8] H.G. Mobtaker, A. Keyhani, A. Mohammadi, SH. Rafiee, A. Akram, “Sensitivity analysis of energy inputs for barley production in Hamedan Province of Iran”, Agric. Ecosyst. Environ. Nederland, vol. 137, pp. 367-372, 2010a.

[9] H.G. Mobtaker, A. Akram, A. Keyhani, “Energy use and Sensitivity analysis of energy inputs for alfalfa production in Iran”, Energy for sustainable development England, (In press).

[10] H.G. Mobtaker, A. Akram, A. Keyhani, “Investigation of energy consumption of perennial

Alfalfa production-Case study: Hamedan province", J. Food Agric. Environ. Finland, vol. 8, pp. 379-381, 2010b.

[11] Anonymous. "Annual Agricultural Statistics. Ministry of Jihad-e-Agriculture of Iran", www.maj.ir (in Persian), 2010.

[12] H. Kizilaslan, "Input-output energy analysis of cherries production in Tokat Province of Turkey", Appl. Energy England, vol. 86, pp. 1354-1358, 2009.

[13] S.A. Hatirli, B. Ozkan, C. Fert, "An econometric analysis of energy input-output in Turkish agriculture", Renewable and Sustainable Energy Reviews England, vol. 9 pp. 608-623, 2005.

[14] J.M. Singh, "On farm energy use pattern in different cropping systems in Haryana, India", Master of Science, Germany, International Institute of Management, University of Flensburg, 2002.

[15] D.S. Shrestha, "Energy use efficiency indicator for agriculture", Available from: http://www.usaskca/agriculture/caedac/PDF/mcrae. 1998.

[16] K.G. Mandal, K.P. Saha, P.K. Ghosh, K.M. Hati, K.K. Bandyopadhyay, "Bioenergy and economic analysis of soybean-based crop production systems in central India", Biomass Bioenergy England, vol. 23(5), pp. 337-345, 2002.

[17] B. Ozkan, H. Akcaoz, C. Fert, "Energy input-output analysis in Turkish agriculture", Renew. Energy England, vol. 29, pp. 39-51, 2004.

[18] C.A. Tsatsarelis, S. Koundouras, "Energetics of baled alfalfa hay production in northern Greece", Agric. Ecosyst. Environ. Nederland, vol. 49, pp. 123-130, 1994.

[19] H. Singh, D. Mishra, N.M. Nahar, M. Ranjan, "Energy use pattern in production agriculture of a typical village in arid zone India: Part II", Energy Convers. Manage. England, vol. 44(7), pp.1053-1067, 2003.

[20] S.A. Hatirli, B. Ozkan, C. Fert, "Energy inputs and crop yield relationship in greenhouse tomato production", Renew. Energy England, vol. 31, pp. 427-438, 2006.

[21] SH. Pishgar Komleh, A. Keyhani, SH. Rafiee, P. Sefeedpary, "Energy use and economic analysis of corn silage production under three cultivated area levels in Tehran province of Iran", Energy England, vol. 36, pp. 3335-3341, 2011.

[22] M. Drechsler, "Sensitivity analysis of complex models". Biological. Conservati. Vol. 86, pp. 401-412, 1998.