Journal of Agricultural Technology 2011 Vol. 7(3): 557-565
Available online http://www.ijat-aatsea.com
ISSN 1686-9141

Investigating the energy consumption in different operations of oilseed productions in Iran

Mousavi Avval, S.H.*, Rafiee, S., Jafari, A. and Mohammadi, A.

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

Mousavi Avval, S.H., Rafiee, S., Jafari, A. and Mohammadi, A. (2011). Investigating the energy consumption in different operations of oilseed productions in Iran. Journal of Agricultural Technology 7(3): 557-565.

The energy consumption in different operations of soybean, canola and sunflower productions in Golestan province of Iran was investigated. This study also focused sketches the environmental footprints of energy use in oilseed production. For these purpose Inquiries on 319 oilseed farms were conducted in 2009/10 production period. The results revealed that soybean gave the highest operational energy input (22235 MJ ha^{-1}); while, total operational energy for canola and sunflower was relatively low as 8317 and 6013 MJ ha^{-1}, respectively. Irrigation operation consumed the highest share of total operational energy in soybean and sunflower productions; it was mainly in the form of electricity energy; however, in canola production, the tillage operation was the most intensive energy consumer, followed by harvesting practice. From this study it was found that increasing energy use efficiency of water pumping systems by good repair and maintenance and employing improved tillage and harvesting practices, such as low till agriculture, could be the pathways to make oilseed productions more environmental friendly and thus reduce their environmental footprints.

Key words: operational energy; soybean; canola; irrigation; environmental impact

Introduction

Energy is a fundamental part of economic development because it provides essential services that maintain economic activity and the quality of human life (Thankappan *et al.*, 2006). The vital role of precious energy in the development of key sectors of economic importance such as industry, transport, and agriculture has motivated many researchers to focus on energy management (Baruah and Dutta, 2007). Energy use in agriculture has developed in response to increasing populations, limited supply of arable land, and a desire to improve the standard of living (Rafiee *et al.*, 2010). Sustainability of production and

*Corresponding Author: S. H. Mousavi Avval; e-mail: sh.mousavi@ut.ac.ir

sustainability of consumption are at risk (Pimentel *et al.*, 2004). Effective use of energy in agriculture is important for sustainable agricultural production; it helps to optimize economic return, preserve fossil fuel reserves and reduce air pollution (Rafiee *et al.*, 2010). Discussions on environmental effects of agricultural production and finite supplies of fossil energy require reliable information on the impact of crop-specific agricultural activities and the sustainability of crop production systems (Pervanchon *et al.,* 2002). Some researches have been conducted on energy use in agricultural production (Kallivroussis *et al.*, 2002; Canakci *et al.*, 2005; Beheshti Tabar *et al.*, 2010). Also, Khan *et al.* (2009) investigated the energy consumption in different operations of wheat, rice and barley production to specify the main pathways for reducing the environmental footprints of water and energy use in the southern Murray Darling Basin.

Considering the importance of energy and oilseeds in Iran, the main objective of the present study was to investigate the energy consumption in different operations of oilseeds productions in Golestan province of Iran. Also, it sketches the environmental footprints of energy use and its potential threat to the growth and stability of food production.

Materials and methods

The three major oilseed crops cultivated in Iran are soybean, sunflower and canola. In Iran, these oilseed crops are mainly produces in Golestan province in the north-east of the country. The data were collected through survey study from the business enterprises in the region. The survey was made in 2010 by interviewing the enterprises that have been produced soybean, canola and sunflower. For calculating the sample size, the simple random sampling method was used (Kizilaslan, 2009). Thus the size of samples was found to be 94, 130 and 95 for soybean, canola and sunflower production, respectively; consequently, the farms from the population were randomly selected.

The data were included the amount of all direct and indirect energy inputs used in different operations and soybean yield as well as socio-economic structures of farms. Energy inputs used in oilseed production were analyzed in terms of various crop production operations, to identify the most energy intensive operation and hence the most promising entry points to reduce the environmental footprints of energy usage. The operations for soybean, canola and sunflower productions were tillage, sowing, irrigation, weeding, fertilizer and chemical application, harvesting and transporting. In these operations, the energy inputs of machinery, diesel fuel, electricity and human labour were used. The output was considered as the oilseed grain production. Electricity and diesel fuel energy inputs were mainly used in direct form at farms; at the field level, these inputs were used for machinery and irrigation water pumping.

The energy equivalent of human labour, electricity and diesel fuel inputs were estimated by multiplying the quantity of each input with its energy coefficient. The energy coefficient of human labour was considered as 1.96 MJ/h, as used by several authors (Mohammadi *et al.*, 2008; Rafiee *et al.*, 2010). Also, the coefficient of 47.80 MJ/L and 11.93 MJ/kWh were used to calculate the energy equivalent of diesel fuel and electricity, respectively (Canakci and Akinci, 2006; Hatirli *et al.*, 2006). For investigating the energy equivalent of output, the coefficient of 25 MJ/kWh was considered (Beheshti Tabar *et al.*, 2010). Energy related to tractor and agricultural machinery was reported in terms of MJ kg^{-1}. The weight of machinery depreciated per hectare of sunflower production during the production period was calculated as follows (Beheshti Tabar *et al.*, 2010):

$$TW = \frac{G \times W_h}{T} \quad (1)$$

where TW is the depreciated machine weight (kg ha^{-1}); G is the total machine weight (kg); W_h is the time that machine used per unit area (h ha^{-1}) and T is the economical life time of machine (h).

Results and discussions

The amount of physical inputs used per hectare of soybean, canola and sunflower production are presented in Table 1. From the table it is evident that, human labour was used as about 190, 79 and 132 h ha^{-1} for soybean, canola and sunflower, respectively. The high use of human labour for soybean production was mainly due to more labour requirement of irrigation, weeding and spraying operations. Also, use of human labour in harvesting of sunflower was found to be high. The consumption of diesel fuel for soybean and canola productions was nearly the same; while, it was considerably lower in sunflower production. The electricity consumption for sunflower and canola productions was found to be as low as 195 and 137 (kWh ha^{-1}), respectively. It was due to lower need for irrigation in these crops. However it was used as high as 1335.9 kWh ha^{-1}, for soybean production. Also, machinery was used as 14.4, 13.9 and 9.9 h per hectare in soybean, canola and sunflower operations. Moreover, the grain yield of soybean, canola and sunflower was found to be 3233, 2152 and 1626 kg ha^{-1}, respectively.

Table 1. Quantities of physical inputs and output for oilseed production in Golestan, Iran.

Item (unit)	Soybean	Canola	Sunflower
A. Inputs			
1. Tillage			
Human labour (h)	11.3	6.8	4.3
Machinery (h)	3.6	6.8	4.3
Diesel fuel (L)	29.2	47.5	31.9
2. Sowing			
Human labour (h)	1.2	1.7	2.4
Machinery (h)	1.2	0.9	0.9
Diesel fuel (L)	7.8	6.7	6.2
3. Irrigation			
Human labour (h)	54.2	4.9	16.7
Diesel fuel (L)	3.3	0.2	2.7
Electricity (kWh)	1336	195.0	137.0
4. Weeding			
Human labour (h)	49.4	42.5	39.8
5. Application			
Human labour (h)	31.9	15.4	6.2
Machinery (h)	4.3	2.1	0.8
Diesel fuel (L)	19.8	11.9	3.4
6. Harvesting			
Human labour (h)	31.6	5.5	49.7
Machinery (h)	1.5	1.8	1.2
Diesel fuel (L)	28.5	26.8	17.9
7. Transportation			
Human labour (h)	10.9	2.2	12.6
Machinery (h)	3.8	2.2	2.7
Diesel fuel (L)	15	8.3	9.9
Total			
Human labour (h)	190.5	79	131.7
Machinery (h)	14.4	13.9	9.9
Diesel fuel (L)	103.6	101.5	72
Electricity (kWh)	1335.9	195	137
B. Output			
1. Grain yield (kg)	3233.1	2152	1626

The detailed information about employed different agricultural machinery and their energy equivalents are presented in Table 2. The results revealed that, the use of machinery energy in sunflower production in compared to soybean and canola was relatively low. This was due to the non-mechanized operations and high dependency of sunflower production to the human labour.

Table 2. The characteristics and energy equivalents of machinery used in soybean production in Golestan, Iran.

Machinery	Soybean		Canola		Sunflower	
	Time ($h\ ha^{-1}$)	**Energy ($MJ\ ha^{-1}$)**	**Time ($h\ ha^{-1}$)**	**Energy ($MJ\ ha^{-1}$)**	**Time ($h\ ha^{-1}$)**	**Energy ($MJ\ ha^{-1}$)**
1. Tractor	12.9	362	12.07	338.9	8.5	239.6
2. Self propelled combine	1.5	389.1	1.80	472.6	1.2	323.6
3. Other machinery		211.8		173.7		113.2
a. Plow	-	-	3.10	25.3	2.1	17.1
b. Cultivator	1	13.1	0.78	9.7	1.3	16.2
c. Disk harrow	2	29	2.69	38.9	2.4	33.9
d. Bund former	0.5	5.6	0.20	2.1	0.3	2.8
e. Planter	1.6	39.2	0.94	35.8	0.4	15.1
f. Fertilizer spreader	0.2	3	1.67	6.17	0.2	3.3
g. Sprayer	4.1	86.4	1.67	34.9	0.6	11.4
h. Trailer	3.8	35.5	2.21	20.8	1.2	13.3
Total		962.9		985.3		676.4

The energy conversion factors for different inputs were used to determine the energy consumption in different operations and output energy for oilseed productions. The results are tabulated in Table 3. The results revealed that soybean has the highest operational energy input (22235 MJ ha^{-1}). Soybean also has the highest yield and hence total energy output.

Total operational energy for canola and sunflower was relatively low as 8317 and 6013 MJ ha^{-1}, respectively. This leans to the view that, in terms of total operational energy, soybean production for food security may have a higher environmental footprint that achieving the same goal through sunflower and canola production.

The distributions of energy associated with different operations of selected crops are comparatively illustrated in Fig. 1. The results showed that, irrigation had the highest contribution from total operational energy in soybean and sunflower, contributed to the total energy by 73% and 30% for the respective crops. Also, 28% from total operational energy of canola production was consumed in irrigation operation. This was mainly due to the high use of electricity in water pumping systems and water in this operation. Singh *et al.* (1990) investigated the energy consumption for paddy-wheat rotation in Punjab; they reported that irrigation consumed the maximum energy in all the farm operations for both paddy (81.9%) and wheat (38.1%) productions.

Table 3. Energy equivalents of inputs and output (MJ ha^{-1}) for oilseed production in Golestan, Iran.

Item (unit)	Soybean	Canola	Sunflower
A. Operations			
1. Tillage	1565.5	2551.6	1715.8
2. Sowing	449.8	386.4	349.6
3. Irrigation	16200	2344	1794
4. Weeding	96.8	83.2	77.9
5. Application	1217.8	701.4	208
6. Harvesting	1811.3	1766	1276
7. Transportation	893.8	484.7	591.9
Total	22235	8317	6013
B. Output			
1. Energy output	80828	53798	40663

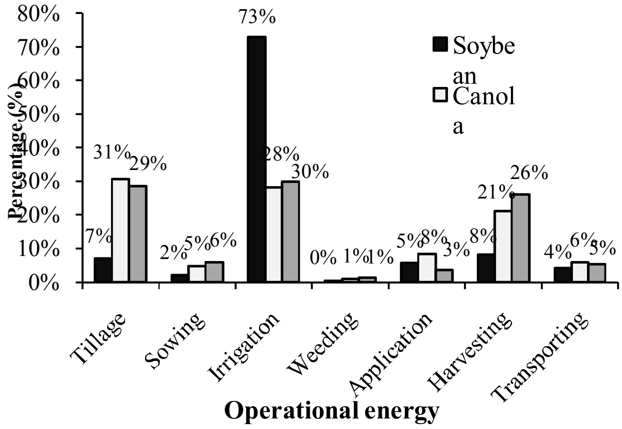

Fig. 1. Distribution of operational energy inputs in oilseed productions

Apart from irrigation, tillage operation consumed 31% and 29% from total energy input for canola and sunflower production, respectively. The share of tillage energy for soybean production was relatively low as 7%; this is due to applying conservation tillage for soybean production. Also, for all the crops, energy input in weeding was the lowest, which was due to the use of traditional tools for removing weeds.

To sum up, in terms of oilseed production operations, irrigation and tillage were the most intensive energy operations, followed by harvesting. This was mainly due to the use of diesel fuel and electricity in these operations. Excessive use of non-renewable energy such as electricity and diesel fuel in crop production operations is not sustainable for a healthy agriculture in the long-term and can cause impacts on human health and ecosystems.

The improper use of machinery and groundwater in agricultural practices may result in land quality degradation such as soil erosion, compaction, salinization and reduction of organic matter. The high water input in soybean farms may exacerbate the problem of soil drainage and excessive leaching of water to shallow groundwater aquifers which may impact groundwater table and soil salinity dynamics (Khan *et al.*, 2009). Also, Soil compaction may be caused by the repetitive and cumulative effect of heavy machinery, resulting in reduction of soil porosity and root penetration and alters the biological activity on the farm scale. On the watershed scale, soil compaction increases surface runoff and water erosion, loss of topsoil and nutrients, and non-point source pollution of water resources (Zalidis *et al.*, 2002).

Thus improved water pumping, tillage and harvesting practices such as good maintenance of pumping systems, low till agriculture or technological upgrade to reduce fossil-fuel inputs by substitution with renewable energy or using machines running on hybrid fuels could be a pathway to make food production more sustainable and environmental friendly and thus reduce its environmental footprint. The development of renewable energy technologies such as farm machinery using bio-diesel or solar power is determined by the agribusiness investor priorities in global market, something beyond farmer's direct control. Governments can play a role through subsidies or other support measures. This nevertheless suggests that factors outside the farming sector will continue to be important for determining the energy usage footprints in agricultural production.

In this study the energy consumption in different operations of soybean, canola and sunflower productions in Golestan province of Iran was investigated. The analysis in terms of crop production operations provide a close insight into the pathways to reduce energy inputs by targeting improvements in specific production operations for each crop. The results revealed that total operational energy input for soybean, canola and sunflower production was 22235, 8317 and 6013 MJ ha^{-1}, respectively.

Energy use in irrigation operation of soybean production was considerably high as 73% from total operational energy input. Further intensification of these irrigated areas to meet future food demand can lead to significant impacts on the environment. This higher dependency on fossil fuel inputs also poses a potential threat to the growth and stability of world food production. Transition towards intensive but more sustainable irrigated agriculture therefore becomes more important for food security than a further intensification alone.

Totally, irrigation, tillage and harvesting operations were the most intensive energy operations in oilseed production. Improving timing, amount and reliability of water application, increasing energy use efficiency of water pumping systems by good repair and maintenance, improved tillage and harvesting practices such as, low till agriculture or technological upgrade to reduce fossil-fuel inputs by substitution with renewable energy or using machines running on hybrid fuels could be the pathways to make oilseed productions more environmental friendly and thus reduce their environmental footprints.

Acknowledgement

The financial support provided by the Research Department of University of Tehran, Iran, is gratefully acknowledged.

References

Baruah, D.C. and Dutta, P.K. (2007). An investigation into the energy use in relation to yield of rice (Oryza sativa) in Assam, India. Agric. Ecosyst. Environ. 120, 185-191.

Beheshti Tabar, I., Keyhani, A. and Rafiee, S. (2010). Energy balance in Iran's agronomy (1990-2006). Renew. Sust. Energy Rev. 14, 849-855.

Canakci, M. and Akinci, I. (2006). Energy use pattern analyses of greenhouse vegetable production. Energy 31, 1243-1256.

Canakci, M., Topakci, M., Akinci, I. and Ozmerzi, A. (2005). Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. Energy Convers. Manage. 46, 655-666.

Hatirli, S.A., Ozkan, B. and Fert, C. (2006). Energy inputs and crop yield relationship in greenhouse tomato production. Renew. Energy 31, 427-438.

Kallivroussis, L., Natsis, A. and Papadakis, G. (2002). The energy balance of sunflower production for biodiesel in Greece. Biosyst. Eng. 81, 347-354.

Khan, S., Khan, M.A., Hanjra, M.A. and Mu, J. (2009). Pathways to reduce the environmental footprints of water and energy inputs in food production. Food Policy 34, 141-149.

Kizilaslan, H. (2009). Input-output energy analysis of cherries production in Tokat Province of Turkey. Appl. Energy 86, 1354-1358.

Mohammadi, A., Tabatabaeefar, A., Shahin, S., Rafiee, S. and Keyhani, A. (2008). Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Convers. Manage. 49, 3566-3570.

Pervanchon, F., Bockstaller, C. and Girardin, P. (2002). Assessment of energy use in arable farming systems by means of an agro-ecological indicator: the energy indicator. Agric. Syst. 72, 149-172.

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbett, E. and Nandagopal, S. (2004). Water resources: agricultural and environmental issues. BioScience 54, 909-918

Rafiee, S ,.Mousavi Avval, S.H. and Mohammadi, A. (2010). Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy 35, 3301-3306.

Singh, S., Singh, M.P. and Bakhshi, R. (1990). Unit energy consumption for paddy-wheat rotation. Energy Convers. Manage. 30, 121-125.
Thankappan, S., Midmore, P. and Jenkins, T. (2006). Conserving energy in smallholder agriculture: A multi-objective programming case-study of northwest India. Ecological Economics 56, 190-208.
Zalidis, G., Stamatiadis, S., Takavakoglou, V., Eskridge, K. and Misopolinos, N. (2002). Impacts of agricultural practices on soil and water quality in the Mediterranean region and proposed assessment methodology. Agric. Ecosyst. Environ. 88, 137-146.

(Received 4 October 2010; accepted 20 March 2011)