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Optimization of Energy Consumption in canola Production Using linear programming "A Case study in Kangavar county", Iran

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ABSTRACT: The canola (*Brassica napus*) is a widely cultivated plant in the gourd family (*Brasicaceae)*. Total land area under canola production in Iran is about 86000 ha which produces average 2.5 ton/ha. Kangavar is important canola producing in Kermanshah Iran. 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. However, more intensive energy use has brought some important human health and environment problems, so efficient use of inputs has become important in terms of sustainable agricultural production. The objective of the present study was to analysis the energy efficiency on canola production systems in Kangavar county of Iran. The results revealed that the total energy input use on canola production is about 37944MJ/ha. The highest share of total energy input was recorded for electricity (61.1%), diesel fuel (15%) and N fertilizer (12%) respectively. the average annual yield for canola production systems were found to be 3246 kg/ha and that their total energy equivalent was 81158 MJ/ha. The amount of energy use efficiency, Energy productivity and net energy was 2.1, 0.08 Kg/MJ and 42213 MJ/ha. result of this study show that by optimization of energy inputs total energy input reduced 6781 MJ/ha.

***Keywords*:** canola, energy, productivity, linear programming

INTRODUCTION

Canola is an important oil crop growing in many part of the world. Canola in Iran is mostly cultivated as a winter annual for oil production and rarely livestock feed. It can be planted in spring as well as can be grown in summer but the seed yield would be decreased due to short growing season and lack of enough water at the end of growing season, thus, winter cropping is preferred. The canola cultivars are slow growing especially in winter and most of them will complete their life cycle in 210 to 270 days (Sharghi et al., 2011). Canola production in Iran is 164000 tons in 2009 that 64.90% of irrigated farming and 35.10% of dry farming have been obtained (Anonymous, 2010). Also in this year, canola cultivation was about 86000 ha that 59.56% is irrigated farming and the rest of that was dry farming (Anonymous, 2010). In developing countries like Iran, agricultural growth is essential for fostering the economic development and meeting the ever higher demands of the growing population. Energy in agriculture is important in terms of crop production and agro processing for value adding. The relation between agriculture and energy is very close. At present productivity and profitability of agriculture depends on energy consumption (Karimi et al.,2008). Energy use in agriculture was developed in response to increasing populations, limited supply of arable land and a desire for higher standards of living. More intensive energy use of fossil fuel, chemical fertilizers, pesticides, machinery and electricity brought some important human health and environmental problems. Thus, efficient use of energy inputs is importance in terms of sustainable farming. Agriculture is closely linked with energy and can as a consumer and supplier of energy (Alam et al., 2005). The energy consumption in the agricultural sector depends to the population employed in the agriculture, the amount of cultivable land and the level of mechanization (Ozkan et al., 2004). An energy analysis is vital for proper management of scarce resources to improve agricultural production. On account of this, we will have efficient and economic production. Moreover, determination of energy consumption in every level of production, help us to obtain which level has the minimum input energy (Chaudhary et al, 2006). Nowadays, in addition common methods, some new methods are invented. One of these modern methods is linear programming

Bender et al. (1984) generalized linear programming model is presented which can be used to optimize agricultural production systems by evaluating the time-varying competition between crops for land, labor and machinery. Audsley (1981) developed a linear programming model for the use of researchers or engineers developing new machines and techniques. The model assesses, within a range of farm conditions, the economic and technical bounds within which a machine must operate, if it is to be commercially viable. The model is also useful for looking at different management strategies for individual farms. In Sartori et al. (2001) The use of linear programming was proposed in formulating mathematical models for optimizing the quantity of residue at harvest, and of the production of energy present in the residues. Results showed that the models have strength as a tool to choose the sugar cane varieties.

Mixed-integer linear programming models were constructed from farm management data, therefore, to examine the viability of biofuel production systems on four typical U.K. farm types (Jones, 1986). Suparaporn (1991) developed a model of linear programming to determine the yield needs in crops on some farms in India. This model was compared with the real production plan. The linear programming in addition to its application in quantifying the needs of the crops, resulted in an increase of 318, 37% in the net income. Whitson et al. (1981) utilized a linear programming approach for the selection of machinery to evaluate crop alternatives of grain sorghum, cotton, soya bean and maize in Texas under weather risk.

In 1993 a model of linear programming was developed for maximizing the net income of the agricultural sector for sugar-alcohol industries. The model was able to describe and simulate the agricultural system of any sugar and/or alcohol mill, thus providing an instrument for optimization of management decision making, useful for operational planning, selection of machinery and varieties, and in other management processes in agriculture (Soffner et al., 1993). Although good results were obtained with this model, it did not take into consideration the facet of residue reduction, which is the present concern preoccupation. Ismintarti et al. (1996) developed a model of linear programming with the purpose of optimizing the utilization of available resources at the mill. Form the results obtained, the mill functioned below its maximum capacity, resulting in high losses in its net income.

Several researchers have worked with linear programming with a single objective (Joshi et al., 1991) and in the majority of cases that objective has been minimization of total cost. Others such as Ramanathan (1995) had handled the optimization problem with an additional objective function such as maximization of revenue return or maximization of overall efficiency. Jana et al. (2005) offers a model which attempts to optimize the direct energy use for different operations in the agricultural sector, taking into consideration certain objective functions against a set of constraints. The exercise is essentially the application of multi-objective fuzzy linear programming techniques in which efforts are made to arrive at a compromise solution among the objectives in a fuzzy environment. This model is capable of accommodating the needs at local level to provide solutions which are sectorally, spatially and sectionally realistic.

The objective of the present study was to energy analysis in canola production on in Iran in terms of energy use efficiency, energy productivity, specific energy, and net energy.

MATERIALS AND METHODS

Kermanshah province has 1.54% of total area of the country and is located in the west of Iran, within 34° 41´ latitude and 46° 75´ longitude. The total area of this province is 2499800 ha, and the farming area is 880095 ha **.** Climate of the region is characterized by an annual average rainfall of 403 mm, distributed 44.3% in winter and 55.7% during spring and autumn. The annual average temperature is 14.20 C, with a monthly maximum of 270C in July and a minimum of -10C in January **.**The study investigated 120 canola producers in Kangavar County. The size of each sample was determined using Eq. (1) derived from Neyman technique (Yamane, 1967).

$$n = \frac{(\sum \mathrm{N_h\ S_h})}{N^2 D^2 + \sum \mathrm{N_h\ S^2{}_h}} \qquad (1)$$

Where n is the required sample size; N is the number of holdings in target population; Nh is the number of the population in the h stratification; Sh is the standard deviation in the h stratification, Sh2 is the variance of h stratification; d is the precision where (ȳ-Ȳ) is the reliability coefficient (1.96 which represents the 95% reliability); D2=d2/z2.For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used Other information was collected from the Ministry of Agriculture departments in Iran. Total energy input and output of these systems were calculated and converted to their energy equivalent. Energy equivalents of inputs and outputs for canola production were obtained from a number of sources (Table 1).

Table 1. Energy equivalents of input and output in canola production systems

Equipment /Inputs	Unit	Energy equivalents	Reference
A. Inputs			
1.Human Labor	H	1.96	(Bojaca & Schrevens, 2010)
2.Machinery	H	62.7	(Erdal et al., 2007; Esengun et al., 2007)
3.Diesel fuel	L	47.8	(Kitani, 1999)
4. Chemical Fertilizer	Kg		
(a) Nitrogen		64.4	(Pimentel, 2006)
(b) Phosphate (P2O5)		11.6	(Ozkan et al., 2004)
5. Pesticides	Kg	114	(Ozkan et al., 2004)
6. Electricity	MJ	1	(Rafiee et al, 2010)
8.Water for Irrigation	M^3	0.63	(Esengun et al., 2007; Hatirli et al., 2006)
9. Seed	Kg	3.6	(singh, 2002)
B. Output			
yield	Kg	25	(Ozkan et al, 2004)

Input energy sources included human labor, machinery, diesel fuel, fertilizers (N, P), chemicals, Electricity, water for irrigation and seeds; while output energy sources was canola production. In this study energy use efficiency, energy productivity and net energy were determined applying standard equations 2-6 (Singh et al., 1997; Burnett, 1982; and Khan et al., 2008).

$$Energy\ use\ efficiency = \frac{Output\ Energy\ (MJ\ ha^{-1})}{Input\ Energy\ (MJ\ ha^{-1})} \quad (2)$$

$$Energy\ productivity = \frac{Grain\ yield\ (Kg\ ha^{-1})}{input\ energy\ (MJ\ ha^{-1})} \quad (3)$$

$$Net\ energy = output\ energy\ (MJ\ ha^{-1}) - input\ energy\ (MJ\ ha^{-1}) \quad (4)$$

In order to optimization of energy productivity linear programming was used. Linear programming is the most powerful technique that can resolve various issues with regard to the conditions apply. A linear programming model has objective function and constrains. Objective function is a mathematical function that consists of decision variables and shown with (Z). It is indicator of model Objective. This function represents maximize utility or minimize the cost as following (Sidho et al., 2004).

$$\mathrm{Max}\ Z = f(x_j) \qquad j = (1,\ldots,n) \quad (6)$$

OR

$$\mathrm{Min}\ Z = f(x_j) \qquad j = (1,\ldots,n) \quad (7)$$

$$Z = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n \quad (8)$$

Constrains consisting of an equation or no equation from decision variables that express the limitations of the model or decision in order to research the model objectives and shown with (C).
Status of decision variables is similar to one of two following case:

$$x_j \geq 0 \qquad j = (1,\ldots,n) \quad (9)$$

or free mark decision variable (xj) that can be in the case of positive values, negative or zero.
Constrain include all limitation can be met on each inputs consumption or yield production. Constrains are as follows;

$$a_{11} x_1 + a_{12} x_2 + \ldots + a_{1n} x_n \ (\leq \mathrm{OR} \geq \mathrm{OR} =)\ b_1$$

:

$$a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{in}x_n\ (\le OR \ge OR =)\ b_i$$
$$:$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n\ (\le OR \ge OR =)\ b_m \quad (10)$$
$$:$$
$$x_1,\ \ _2, \ldots, x_n \ge 0\ OR\ (\text{freemark decision variables})$$

In this study with linear programming and considering all the conditions and limitations the optimal pattern were determining. Solving of problem was done by the WINQSB software

Generally, inputs used in canola production in this region was divided into 9 groups including that: labor (x1), machinery (x2), diesel fuel (x3), N fertilizer (x4), P fertilizer (x5), Pesticides (x6), seed (x7), water for irrigation (x8) and Electricity(x9). In this study objective function is maximizing energy productivity. One of the ways for the maximizing energy productivity is minimizing amount of energy input. Objective function is equal to;

$$Z = \text{Maximize}\ E_p = \text{Maximize}\ \frac{y}{\sum x_i e_i} \qquad i = (1,2,\ldots,8) \quad (11)$$

$$Z = \text{Minimize}\ E_{in} = \text{Minimize} \sum x_i e_i \qquad i = (1,2,\ldots,8) \quad (12)$$

$$x_i e_i \ge e_i \quad (13)$$

$$x_i \ge A_i \quad (14)$$

$$e_i \ge 0 \quad (15)$$

$$Z = \text{Minimize}\ (1.96x_1 + 62.7x_2 + 47.8x_3 + 64.4x_4 + 11.1x_5 + 114x_6 + 3.6x_7 + 0.63x_8 + 1x9) \quad (16)$$

Where EP is energy productivity, E_{in} is total energy input, x_i is amount of used input, Ai is the minimum amount recommended, e_i is energy equivalent of x_i, and x1, x2, x3, x4, x5, x6, x7, x8 and x9 is quantity of labor, machinery, diesel fuel, N fertilizer, P fertilizer, Pesticides, seed, water for irrigation and Electricity respectively.

Constrains result from regional conditions, expert analysis's and production system by interview with growers and including:

$$C_1 : 16 \le x_1 \le 35 \quad (17)$$
$$C_2 : 10 \le x_2 \le 23 \quad (18)$$
$$C_3 : 100 \le x_3 \le 145 \quad (19)$$
$$C_4 : 49.5 \le x_4 \le 99 \quad (20)$$
$$C_5 : 23 \le x_5 \le 46 \quad (21)$$
$$C_6 : 1.5 \le x_6 \le 3.5 \quad (22)$$
$$C_7 : 6 \le x_7 \le 12 \quad (23)$$
$$C_8 : 3400 \le x_8 \le 4600 \quad (24)$$
$$C_9 : 19833 \le x_9 \le 26833 \quad (25)$$
$$C_{10} : x_1 + x_2 \ge 27 \quad (26)$$
$$C_{11} : x_3 + x_4 + x_5 \ge 182.5 \quad (27)$$
$$C_{12} : x_6 + x_7 \ge 8 \quad (28)$$
$$C_{13} : x_8 + x_9 \ge 23233 \quad (29)$$

RESULTS AND DISCUSSION

The inputs used in canola production and their energy equivalents, presented in table 2. The results revealed that the total energy input in greenhouse canola systems was 37944 $MJha^{-1}$. Ozkan et al (2007) reported that the total input energy in greenhouse and open field grape production were 24513.0 and 23640.9$MJha^{-1}$ that of this amount the highest share was related to electricity(28%) in greenhouse cucumber production and diesel fuel(32%) in open-field systems. In this study the average annual yield for canola production systems were found to be 3246 kg ha^{-1} and that their total energy equivalent was 81158 $MJha^{-1}$.

Table 2. Energy equivalents of input and output in canola production systems.

Equipment /Inputs	Quantity used per unit area (ha)	Energy equivalents
1.Human Labor	23	42.6
2.Machinery	16	1012.6
3.Diesel fuel	119.8	5730.4
4. Nitrogen Fertilizer	71.25	4573.6
5. Phosphate (P2O5) Fertilizer	29.9	331.8
6. Pesticides	2.4	280.7
7. Seed	8.9	32.2
8.Water for Irrigation	4012	2528
9. Electricity	23408	23408
Total energy input		37944
B. total energy Output	3246	81158

Indicators of energy use in canola production systems are shown in table 3. The amount of energy use efficiency was 2.1. Energy use efficiency in open-field systems was reported 2.80 for maize in Turkey (Canakci et al, 2005), 1.04 for chickpea in Iran (Salami and Ahmadi, 2010), 2.12 and 2.05 for organic and non organic lentil (Asakereh et al,2010), 1.58 for kiwifruit in Iran (Mohammad et al, 2010). Energy use efficiency was 0.32, 0.19, 0.31, and 0.23 for greenhouse tomato, pepper, cucumber and eggplant respectively (Canakci and Akinci, 2006). Energy use efficiency can be increased by improving crop biomass production or reducing energy application. Energy productivity was 0.08 $KgMJ^{-1}$. Amount of energy productivity was 0.65 $MJkg^{-1}$ for sugar beet (Erdal et al., 2007), 10.43 $MJkg^{-1}$ for irrigated wheat (Ghiyasi et al., 2008), and 5.87 $MJkg^{-1}$ for rainfed wheat in Turkey (Adnan et al; 2009). Net energy (total output energy minus total input energy), in canola production systems was 43213 $MJha^{-1}$.

Table 3. Indicators of energy use in canola production systems.

Indicators	*Quantity*	*Unit*
Inputs Energy	37944	MJ ha^{-1}
Output Energy	81158	MJ ha^{-1}
Grain Yield	3246	Kg ha^{-1}
Energy Use Efficiency	2.1	%
Energy Productivity	0.08	Kg MJ^{-1}
Net Energy	43213	MJ ha^{-1}

The share of important energy inputs of total inputs energy are shown approximately in Figure 1. The highest share of total energy input was recorded for electricity (61.1%), diesel fuel (15%) and N fertilizer (12%) respectively. Ozkan et al (2004) reported that the highest share of total input energy for greenhouse tomato, cucumber and eggplant was related to diesel fuel by 32.17, 42.64, and 31.30 percent, respectively.

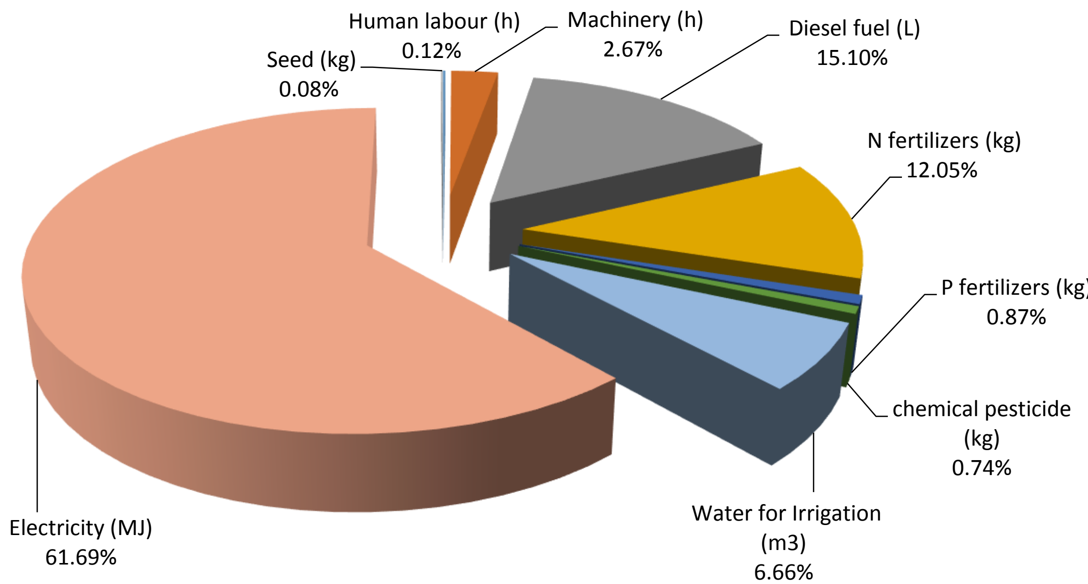

Figure 1. Share of important energy inputs of total input energy

For optimizing of energy consumption pattern WINQSB Software was used. To solving the problem an objective function with constraints was designed. Solving of problem was done by Simplex method. Results of optimization energy consumption pattern were shown in Table 4.

Table 4. Optimized amount of energy inputs and energy saved

Equipment /Inputs	Optimize quantity	Energy equivalents (MJ/ha)	Energy saved(MJ/ha)
1.Human Labor (h)	17	33.3	12.9
2.Machinery (h)	10	627	399
3.Diesel fuel (l)	100	4780	950
4. Nitrogen Fertilizer (kg)	49.5	3187	1386
5. Phosphate (P2O5) Fertilizer (kg)	33	366	-
6. Pesticides (kg)	1.5	171	109
7. Seed (kg)	6.5	23.4	8.8
8.Water for Irrigation (m3)	3400	2142	386
9. Electricity (MJ)	19833	19833	3575
Total energy input (MJ)		31163	6781

By optimization of energy inputs (Human labor, Machinery, Diesel fuel, Nitrogen Fertilizer, Pesticides, seed, water for irrigation and Electricity) reduced 12.9, 399, 950, 1386, 109, 8.8, 386 and 3575 MJ ha^{-1} respectively. Total energy input reduced 6781 MJ ha^{-1}. In this status energy efficiency, energy productivity and net energy were 2.6, 0.1 Kg MJ^{-1} and 49995 MJ ha^{-1} respectively. Indicators of energy use in canola production systems with optimized status are shown in table 5.

Table 5. Indicators of energy use in canola production systems with optimized status

Indicators	Quantity	Unit
Inputs Energy	31163.8	MJ ha^{-1}
Output Energy	81158	MJ ha^{-1}
Energy Use Efficiency	2.6	%
Energy Productivity	0.1	Kg MJ^{-1}
Net Energy	49995	MJ ha^{-1}

CONCLUSION

In this study, the inputs and output energy requirements for canola production systems were assessed in the Kangavar county of Iran by using a face to face questionnaire performed with farmers. The results revealed that the total energy input use on canola production is about 37944MJ/ha, The main factor resulting in excessive energy use on canola production is electricity. By optimization of energy inputs (Human labor, Machinery, Diesel fuel, Nitrogen

Fertilizer, Pesticides, seed, water for irrigation and Electricity) reduced 12.9, 399, 950, 1386, 109, 8.8, 386 and 3575 MJ ha^{-1} respectively. Total energy input reduced 6781 MJ ha^{-1}.

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