Biological Forum – An International Journal **7**(1): 1131-1136(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Assess the Energy Efficiency of Rapeseed (*Brassica napus* L.) Production in the Mazandaran province: A case study of Amol city

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(Received 02 March, 2015, Accepted 17 April, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Energy consumption in the world and Iran has increased in recent years. Recently, farmers apply more energy to produce food. To achieve the best performance, review and analyze the energy of food production is very important. On the other hand, the economic analysis for the detection performance of the product is essential. In this study, the energy equivalences of input-output used in the winter oilseed rape (*Brassica napus* L.) or Canola have been investigated in Mazandaran province of Iran. The required information has been achieved from the questionnaire with the help of 71 farmers from 5 villages in Amol city, Mazandaran province. Energy analysis results showed that total input energy in production was 29332.36 MJ/ha. Of all the inputs, the fertilizer (mostly N fertilizer) has the biggest share in the total energy with a 65.11 % (19101.25.8 MJ/ha) that show, canola production severely dependent on fertilizer. Fertilizer energy is followed by diesel fuel energy which was 30.96 % (9082 MJ/ha). Energy of machinery and seed was 3.13 % and 0.51 % of total input energy, respectively. Average output energy of canola was found 41230 MJ/ha. Direct energy was 31.23 % while indirect energy was 98.77 % of total input energy. Nonrenewable energy was 99.215 % while renewable energy was 0.785 % of total input energy.

Keywords: Canola, Mazandaran, Energy analysis, Direct energy, Renewable energy.

INTRODUCTION

Agriculture to meet the growing need for food for a growing world population and to provide sufficient food and good quality is extremely dependent to energy consumption. Thus, energy use in agriculture increases by increasing population, limited arable land, and increasing of life quality. On the other hand, due to limited resources and the adverse effects resulting from the proper use of various energy sources on human health and the environment, the need to examine the pattern of energy consumption in agriculture is inevitable (Hatirli, *et al.,* 2005). Considering the energy crisis, increasing fossil fuel consumption and consequently an increase in emissions of various greenhouse gases into the environment, reducing energy consumption as much as possible is necessary. Energy consumption in the world and also in Iran has increased in recent years and recently farmers apply more energy to produce food (Beheshti *et al.,* 2010).

Energy analysis for sustainable management of resources is essential for agricultural production and thus efficient production and economic activity will be determined. Analysis of input and output energy of agricultural systems enables policy makers and producers to investigate interactions between energy consumption and economic cost of producing a product (Yilmaz *et al.,* 2005). In agriculture, energy is produced and also consumed. It uses large quantities of locally available non-commercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of electricity, diesel, plant protection, fertilizer, chemical, irrigation water, machinery etc (Taheri-Garavand *et al.,* 2010). Proficiency use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh *et al.,* 2002). If the increase in energy consumption in agriculture continues, using more inputs instead of expansion of arable land will be only chance for producers to increase output. Therefore, the energy consumption in agriculture has been a problem. For this purpose, it is necessary to model the energy consumption of different ecological systems of agricultural production is carefully examined and analyzed. One of the most useful methods in the analysis of agricultural sustainability is energy applying as a calculating tool (Ghorbani *et al.,* 2011, Ceccon and Giovanardi 2002).

By analyzing the energy consumption and determining the share of renewable and non-renewable energies that directly and indirectly involved in the production, increasing the efficiency and productivity of the soil and water resources and chemical inputs and the possible establishment of an ecological production system can be carefully investigated. Many studies are conducted in the field of energy efficiency and balance in agricultural production (Mousavi-Avval *et al.*, 2011, Mohammadi *et al.*, 2008, Heidari and Omid 2011, Mohammadi and Omid 2010, Erdal *et al.*, 2007, Fuksa *et al.*, 2013. The most appropriate method of balancing energy in crop production is process analysis in which fossil energy is considered rather than solar energy and manpower. Rathke and Diepenbrock 2006, Chamsing *et al.*, 2006, Mandal *et al.*, 2002. Gundogmus 2006, Demircan *et al.*, 2006).

In Diepenbrock's approach, fossil energy input is cleaved to direct and indirect input components. Direct energy input includes the consumption of diesel fuel required for field operations taking into account the influences of management and location conditions. Thereto, energy consumption for manufacturing of agricultural machines is also considered as direct energy input. Indirect energy inputs consist of seed material, plant protection agents, fertilizers and operation of machines (Diepenbrock 2012).

Oilseed rape (*Brassica napus* L.) or Canola is one of the world's major oilseed crops and a rapid increase in its production has been observed during the recent years in all over the world (Basharat *et al.*, 2014, Zhang *et al.*, 2010). Moreover its role as the most important source of meal oil in the human diet, the growing demand for canola oil is also fuelled by its increasing use as a renewable energy source in recent decades. Rapeseed oil is primarily composed of various triacylglycerols, molecules that consist of three fatty acid chains esterified to glycerol, and its subsequent combustion instead of conventional diesel reduces greenhouse gas emissions by 40% (Durrett *et al.*, 2008). Original varieties of rapeseed had high levels of erucic acid and glucosinolates, making them inappropriate for human consumption. Breeding experiments led to the progression of rapeseed varieties that contains lower amounts of these undesirable compounds. One of these varieties is Canola and became commercially important in the 1960s. Canola with less than 2 percents erucic acid in the oil and less than 30 micromoles per gram of glucosinolates in the oil-free meal is identified as a high quality and healthy edible oil, or as a potential source for manufacturing a wide variety of environmentally-friendly products such as biodiesel and bioplastics. The remaining canola meal after oil extraction usually contains 35-40 percents protein content and is commonly used as an animal feed or a fertilizer (Edwards, 2005). So, canola is suitable for human consumption. The cultivation of oilseed rape in Iran was about 100 thousand hectares with a production of 164 thousand tons in 2014, that more than 15 percents of them was related to the Mazandaran province.

In this work, portion of direct and indirect energy, renewable and non-renewable energy in canola production in Amol country of Iran have been investigated. This study can help to stability of autumnal implant.

MATERIALS AND METHOD

A. The statistical Community

Each study is needed to run the exact model which according to the first path to the final goal of the project is developed and implemented. Data were collected from 71 canola farms in the Mazanderan province of Iran (Amol city) by using a face to face questionnaire in December 2014. The simple random sampling method was applied to determine survey volume (Kizilaslan 2009), from: $n = \frac{N \times S^2 \times T^2}{(N-1) \times D^2 + S^2 \times T^2}$ (1)

Where, n is the required sample size, S is the standard deviation, T is the T-value at 95% confidence limit, N is the number of holding in target population and D is the acceptable error [12].

B. Geographical Location

Amol city is located in the north of Iran, within 52° 21' east longitude and 36° 25' north latitude. Amol is located on the Haraz river bank. It is less than 20 kilometres (12 mi) south of the Caspian Sea and less than 10 kilometres (6.2 mi) north of the Alborz Mountains. It is 180 kilometres (110 mi) from Tehran, and 60 kilometres (37 mi) west of the provincial administrative center, Sari (www. en.wikipedia.org/wiki/Amol.). In this area, canola grows in dry farming method.

C. Energy Analysis Methodology

Energy analysis was performed to determine the Output- input ratio, Energy productivity, Net energy gain and Specific energy. In order to calculate these indexes, the data have been converted into output and input energy levels using equivalent energy values for each commodity and input. Energy equivalents shown in Table 1 were used for estimation.

In this study, according to information obtained from the questionnaires, the amounts of inputs used in the production of canola were specified in order to calculate the energy equivalences. Energy input consist of human labor, machinery, diesel fuel, chemical fertilizer, pesticides and seed amounts and output yield consist of Canola grain. The input energy is also divided into direct and indirect and renewable and non-renewable forms.

Table 1: Energy equivalent of inputs and outputs in canola production.

Item	Unit	Energy equivalent (MJ/unit)	Reference
Inputs			
Labour	h	1.96	[3], [26], [27]
Diesel fuel	L	47.8	[27]
Tractor	kg	138	[27]
Plow	kg	180	[27]
Sprayer	kg	129	[27]
Equipment of fertilizing	kg	129	[27]
Trails	kg	138	[27]
Thresher	kg	148	[27]
Nitrogen fertilizer (N)	kg	74.2	[28]
Phosphorus (P_2O_5)	kg	17.4	[27]
pesticide	kg	295	[27]
Seed	kg	21.7	[27]
Output			
canola	kg	21.7	[29]

Indirect energy consists of pesticide, machinery, seeds and fertilizers energy while direct energy covered human labor and diesel fuel used in the canola production. Non-renewable energy consists of machinery, diesel, fertilizers and pesticide, and renewable energy includes seeds and human labor.

(i) Fuel Energy. To calculate the energy content of fuels used in different operations, the following equation has been used: $E_p = Q_i \times E_i$ …(2)
Where, E_p is fuel energy (MJ/ha), Q_i is amount of consumed fuel (L/ha) and E_i is energy per unit of fuel (MJ/L).

(ii) Machinary and Equipments Energy. To calculate the energy content of Machinary and Equipments used in different operations, the following equation has been used: $ME = E\frac{G}{T} \times G_t$ ... (3)
Where, ME is machinary and equipments energy (MJ/ha), E is machinery production energy equal to a constant value (62.7 MJ/kg), G is weight of machinery (kg), T is useful life of machinery (h) and G_t is total number of working hours per an agricultural season (h/ha).

(iii) Fertilizers and Chemical Pesticides Energy. To calculate the energy content of fertilizers and chemical pesticides, the following equation has been used: $E_f = W_t \times E_i$ …(4)
Where, E_f is energy content of fertilizers and chemical pesticides (MJ/ha), W_t is weight of fertilizers and pesticides (kg/ha), E_i is energy per one kg of fertilizers and pesticides (MJ/kg).

(iv) Seed Energy. According to the farmer's responses in the questionnaires, the seed content has been determined. To calculate the energy content of seed, the following equation has been used: $E_s = W_i \times E_i$ …(5)
Where, E_s is seed energy (MJ/ha), W_i is weight of seed (kg/ha) and E_i is energy per one kg of seed (MJ/kg).

(v) Labor Energy. The Labor energy can be calculated from the following equation:

$E_l = W_l \times E_i$ …(6)

Where, El is labor energy (MJ/ha), Wl is number of labor (n/ha) and Ei is energy per one each labor (MJ/n).

(vi) Output (Canola) Energy. The output (Canola) energy can be calculated from equation (7):

$$\text{Colza Energy}\left(\frac{\text{MJ}}{\text{ha}}\right) = Colza\ Yield\left(\frac{\text{kg}}{\text{ha}}\right) \times Unit\ Enery\left(\frac{\text{MJ}}{\text{kg}}\right) \quad (7)$$

Where, unit energy is the energy of one kg of colza.

(vii) Calculation of energy indexes. The energy indexes are defined according to following equations:
Output-Input ratio = (Output Energy (MJ/ha))/(Input Energy (MJ/ha)) …(8)
Energy Productivity = (Canola Yield (kg/ha))/(Input Energy (MJ/ha)) …(9)
Net Energy Gain = Energy Output (MJ/ha)- Energy Input (MJ/ha) …(10)
Specific Energy = (Input Energy (MJ/ha))/(Canola Yield (kg/ha)) …(11)

RESULTS AND DISCUSSION

A. Structural data of canola farms

In Amol city, canola cultivation is in form of fry farming.

The average land size of canola in area is 2.1 hectares but the average of each plot size of cultivation is about 0.81 hectares. Because of lack of integration of farm in the region, tractors and equipment in the production of Canola production in Amol city is mechanized and intensively dependent on commercial input. A Massey Ferguson 400 tractor, 80 hp, was used in operations of tillage, transporting and fertilizing and spraying. Agricultural experience of farmers was 17.8 years while experience of canola production was 6.2 years. About 78% of farmers just did farming and the rest.

B. Energy Analysis Results

According to energy equivalences and result of questionnaires, energy analysis was done. The calculated values of input and output energy are illustrated in Table 2. Basic information on energy inputs and Canola yields were entered into Excel and SPSS 21 spreadsheets. Table 2 show that total input energy was 29332.36 MJ/ha and total output energy was 39060 MJ/ha. From among all inputs, the Nitrogen canola were employed in the form of rent, personal and collective as proportion of each form were 72%, 15.5% and 12.5%, respectively. About 91% of canola farms are private and the rest are rental. (N) has the biggest proportion in the total input energy with 60.71% (17808 MJ/ha). Proportion of the fertilizer (consist of P_2O_5, Nitrogen, pesticide) in the total energy was 65.11% (18809.8 MJ/ha) that show, canola production intensively dependent on fertilizer. After fertilizer energy diesel fuel energy was the highest with 30.96% (9082 MJ/ha). Diesel fuel was mainly used for operating tractor and combine harvester. Because of mechanized operation in canola production, use of human labor was low (0.27% of total input energy), but it was very important input in increasing production yield. Ultimately, energy of seed and machinery was 0.51% and 3.13% of total input energy, respectively. Figure (1) shows the proportion of each item in total input energy.

Table 2: Calculated values of input and output energy.

Item			Energy MJ/ha	Energy %
Inputs	Direct	Diesel fuel	9082	30.96
		Labor	78.4	0.27
	Indirect	Machinery	918.81	3.13
		Phosphorus (P_2O_5)	1131	3.85
		Nitrogen (N)	17808	60.71
		Pesticide	162.25	0.55
		Seed	151.9	0.51
Total inputs			29332.36	100
Output		Colza	39060	100
Total output			39060	100

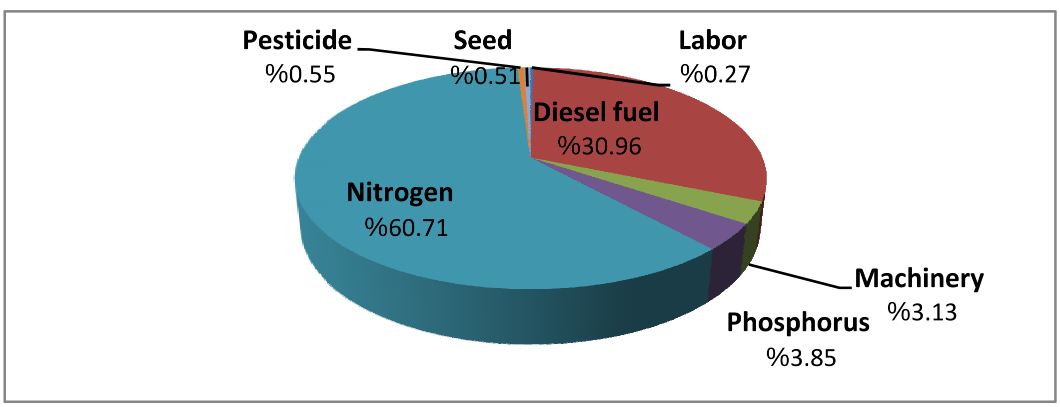

Fig. 1. Proportion of each item in input energy.

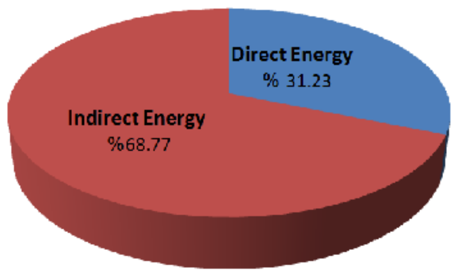

Fig. 2. Proportion of direct and indirect energies in input energy.

Moreover, direct energy was 31.23% while indirect energy was 68.77% of total input energy (Fig. 2). Total output energy of canola was 39060 MJ/ha.

According to results, 99.215% of total energy input resulted from non-renewable and 0.785% from renewable energy (Fig. 3).

The energy indexes were calculated by Eq(8)-Eq(11). The result of this calculation can be seen in Table 3.

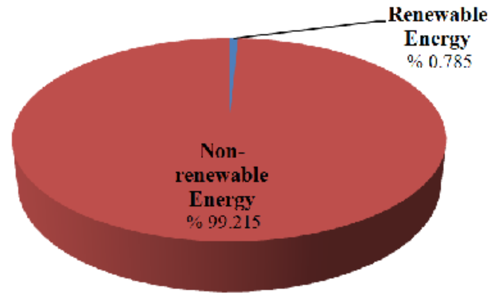

Fig. 3. Proportion of renewable and non- renewable energies in input energy.

Table 3: Energy indexes value in canola production in Amol city.

Index	Calculated Value
Output-Input ratio	1.3316
Energy Productivity (kg/MJ)	0.0613
Net Energy Gain (MJ/ha)	9727.64
Specific Energy (MJ/kg)	16.296

The energy productivity and output-input energy ratio were calculated as 0.0613 and 1.3316 kg/MJ, respectively. Net energy gain and specific energy were 9727.64 MJ/ha and 16.296 MJ/kg, respectively. The results show that the prevalent energy use pattern among the investigated farms in Amol city is based on non-renewable energy in the canola production. Thus, this current method of production caused serious environmental problem.

CONCLUSION

In this study, energy analysis of canola production in Amol city of Iran was investigated. Data were collected from 71 farmers which were selected on random sampling method. Total Energy consumption was 29332.36 MJ/ha. From among all inputs, the Nitrogen (N) has the biggest proportion in the total input energy with 60.71% (17808 MJ/ha). Proportion of the fertilizer (consist of P_2O_5, Nitrogen, pesticide) in the total energy was 65.11% (18809.8 MJ/ha) that show, canola production intensively dependent on fertilizer. After fertilizer energy diesel fuel energy was the highest with 30.96% (9082 MJ/ha). Energy productivity and input-output energy ratio were calculated, 0.0613 kg/MJ and 1.3316, respectively. Direct energy was 31.23% while indirect energy was 68.77% of total input energy. Non-renewable energy was 99.215% total input energy. This indicates that canola production needs to progress the efficiency of energy consumption in production and to employ renewable energy.

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