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An analysis of energy use efficiency of canola production in Turkey

G. Unakitan*, H. Hurma, F. Yilmaz

Namik Kemal University, Faculty of Agriculture, Department of Agricultural Economics, Tekirdağ, Turkey

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ABSTRACT

In this study, a survey and economic analysis regarding the use of input have been performed with canola farmers in the Trakya region of Turkey; survey data were obtained from 100 farmers, face-to-face. The average energy use efficiency is 4.68 and this value increases as farm size increases; according to the results of this study, energy is used more efficiently in large farms. The difference between average input and output energy is 67259.36 (MJ ha^{-1}). The specific energies of small, medium, and large farms are 62584.37, 69836.21, and 74405.43 respectively. The ratio of direct and indirect energy sources are 24.69%, and 75.31% respectively, and the benefit–cost ratio of canola production is 2.09.

1. Introduction

The agricultural sector plays an important role in the Turkish economy. Over the past few years, the share of the agricultural sector decreased annually due to industrial and service sector growth. While the share of the agricultural sector in Turkey's total GDP (Gross Domestic Product) was 35% in 1970, it decreased to 9.2% in 2008. Despite this, 30% of the population is still employed in agricultural sector [1].

The total agricultural area in Turkey is about 22 million hectares; oil seeds are cultivated in 6% of this area. The cotton cultivated areas vary from 550,000 to 750,000 ha, and sunflower cultivated areas vary from 500,000 to 600,000 ha. Canola was bred from rapeseed, which has high amounts of erucic acid. In recent years, canola production began to increase as a high-quality oilseed. While there were 1700 canola-sown hectares in 2004, it rapidly increased to 10,683 ha in 2007.

Energy is a fundamental part of economic development because it provides essential services that maintain economic activity and the quality of human life [2]. 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 [3]. 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 [4]. In all societies, these factors have encouraged an increase in energy input in order to maximize yields, minimize labour-intensive practices, or both [5]. Agriculture uses energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, and for lighting on the farm; it is also used indirectly in the fertilizers and chemicals produced off the farm [6].

Energy needs are not only increasing in the agricultural sector, but in all sectors involving human activities. Turkey's agricultural energy consumption has increased annually, but more intensive energy use has caused some important health and environmental problems [7]. Efficient energy use is one of the principal requirements of sustainable agriculture [8]; the objective of this study was to compare the energy use of canola production of different farm sizes in the Trakya region of Turkey. Specifically, energy use efficiency, energy productivity, specific energy, and net energy are investigated, as is direct, indirect energy usage, renewable and non-renewable energy usage, and benefit–cost ratio of all canola producers.

Generally, energy input output analyses determine energy efficiency or the impact of energy consumption on an environment. There are several studies that determine the energy usage efficiencies of various agricultural products, such as potatoes [4], dry apricots [5], sugar beets [9], greenhouse tomatoes [10], wheat [7,11–16], rice, cassava [15], melons and watermelons, maize, sesame [12], greenhouse vegetables [6,12,17,18], citrus [19], cotton [12,20–23], cluster beans, mustard, apples [24], cherries [25], tomato [26], sweet cherry [27], olive groves [28], apricot [29], peaches [30], soybeans [31], sunflower seeds [32,33], oilseed rape [34], wheat, maize [35] and other studies about energy consumption [36,37].

2. Material and methods

In this study, the usage data of canola farmers in Trakya are obtained using surveys. According to "Leader Farmers Association",

* Corresponding author. Tel./fax: +90 282 293 14 42 128.
E-mail address: unakitan@nku.edu.tr (G. Unakitan).

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there were 270 Trakyan canola farmers in 2007, and the average farm size is 83 decares, with a standard deviation of 53.2 decares. A random sampling method was used; the sample size was calculated using Equation (1) [38]. The permissible error in the sample size was defined to be 10% of the mean for a 95% confidence interval.

$$n = \frac{N \cdot \sigma^2}{(N-1)\sigma_x^2 + \sigma^2} \tag{1}$$

where; n = sample size, N = population volume, d = sampling error, σ = standard deviation, and σ_x = standard deviation of sample mean ($\sigma_x = d/Z_{\alpha/2}$). The sample size was 100, and was distributed homogeneously in the provinces.

The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labour, machinery, diesel, fertilizer, pesticides and seed amounts, and output yield values of canola have been used to estimate the energy ratio. Energy equivalents, shown in Table 1, were used for estimation; these coefficients were adapted from several literature sources that best fit the conditions in Turkey; the sources of mechanical energy used on the selected farms include tractors and diesel oil. The mechanical energy was computed regarding total fuel consumption (l ha^{-1}) in various operations; therefore, the energy consumed was calculated using conversion factors, and was expressed in MJ ha^{-1} [26]. The energy of a tractor and its equipment reveals the amount of energy needed for unit weights and calculates repair and care energy, transport energy, total machine weight, and average economic life.

The output–input energy ratio (*energy use efficiency*) is one of the indices that show the energy efficiency of agriculture. In particular, this ratio, which is calculated by the ratio of input fossil fuel energy and output food energy, has been used to express the ineffectiveness of crop production in developed countries [45]. The energy use efficiency was calculated for canola production in various farm size groups, which were classified as small (<5 ha), medium (between 5 and 10 ha), or large farms (>10 ha) according to their canola-sown areas. An increase in the ratio indicates improvement in energy efficiency, and vice versa. Changes in efficiency can be both short and long term, and will often reflect changes in technology, government policies, weather patterns, or farm management practices. By carefully evaluating the ratios, it is possible to determine trends in the energy efficiency of agricultural production, and to explain these trends by attributing each change to various occurrences within the industry.

Table 1
Energy equivalents of inputs and outputs in agricultural production.

	Energy Equivalent (MJ $unit^{-1}$)	References
Inputs		
Labour (h)	1.96	[18,31,41,42]
Machinery (h)		
Tractor	62.70	[12,41,42]
Combine	87.63	[12,43]
Pesticides (kg)		
Insecticides	278	[44,45,46]
Herbicides	288	[38,39,40]
Fungicide	276	[44]
Fertilizer (kg)		
Nitrogen	66.14	[31,42]
Phosphorus	11.15	[31,42]
Diesel (l)	56.31	[18,41,42]
Seed (kg)	29.20	[47]
Output		
Canola (kg)	27.60	[47]

Basic information regarding energy inputs and canola yields were entered into spreadsheets. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (*energy use efficiency*) (Equation (2)), energy productivity (Equation (3)), specific energy (Equation (4)), and net energy (Equation (5)) are calculated using the following equations:

$$\text{Energy use efficiency} = \frac{\text{Energy output}\left(\text{MJ ha}^{-1}\right)}{\text{Energy input}\left(\text{MJ ha}^{-1}\right)} \tag{2}$$

$$\text{Energy productivity} = \frac{\text{Yield}\left(\text{kg ha}^{-1}\right)}{\text{Energy input}\left(\text{MJ ha}^{-1}\right)} \tag{3}$$

$$\text{Specific energy} = \frac{\text{Energy input}\left(\text{MJ ha}^{-1}\right)}{\text{Yield}\left(\text{kg ha}^{-1}\right)} \tag{4}$$

$$\text{Net energy} = \text{Energy output}\left(\text{MJ ha}^{-1}\right) - \text{Energy input}\left(\text{MJ ha}^{-1}\right) \tag{5}$$

Indirect energy includes energy that is embodied in seeds, fertilizers, manure, chemicals, and machinery; direct energy includes human labour and diesel that was used in canola production. Non-renewable energy includes diesel, chemical, fertilizers and machinery; renewable energy consists of human labour, seeds, and manure. In the last part of the research, a production cost analysis of canola production was investigated, and the net profit and benefit–cost ratio were calculated. The net return was calculated by subtracting the total cost of production from the gross value of production per hectare; the benefit–cost ratio was calculated by dividing the gross value of production by the total cost of production per hectare.

3. Results

In this study, the average farm size of the survey participants is 8.40 ha. Farms are classified into 3 groups based on their sizes; Table 2 displays a comprehensive summary of production inputs and outputs for different farm groups. The average labour usage is 21.98 h/ha in the survey participants. Labour usage decreases while farm size increases; the labour usage of the small farms is 24.70 h/ha, while large farms have a labour usage of 17.52 h/ha. The farms use tractor pull power rather than animal or electric power: the average tractor pull power usage is 16.39 h/ha. Like the labour usage, tractor power usage also decreases while farm size increases. The average diesel consumption is 79.45 l/ha: 78.13 l/ha, 80.54 l/ha, and 81.05 l/ha for small, medium, and large farms, respectively. Pull power hours decrease and diesel consumption increase while farm size increases; this is due to the increasing horsepower of the tractors on larger farms. Tractor horse powers of the small, medium, and large farms are 81.62 hp, 95.66 hp, and 102.78 hp, respectively.

In the study, the average total fertilizer usage is 219.52 kg/ha (189.6 kg/ha Nitrogen, 29.92 kg/ha Phosphorus). Farmers with more than 10 ha use the least amount of fertilizer: 205.23 kg/ha. According to this result, increasing farm size has an advantage for the scale economies. The overall pesticide use of the farms is 2.71 l/ha; 66% of which is herbicides, and the average seed usage is 4.42 kg/ha. Like other inputs, large farms use less seed per hectares than the smaller farms (4.02 kg/ha).