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Energy inputs – yield relationship and cost analysis of kiwifruit production in Iran

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ABSTRACT

This study examines energy consumption of inputs and output used in kiwifruit production, and to find relationship between energy inputs and yield in Mazandaran, Iran. For this purpose, the data were collected from 86 kiwifruit orchards which were selected based on random sampling method. The results indicated that total energy inputs were 30285.62 MJ ha^{-1}. About 47% of this was generated by total fertilizer including farmyard manure, 28% from diesel fuel and machinery. About 70% of the total energy inputs used in kiwifruit production was indirect while only about 30% was direct. Econometric estimation results revealed that energy inputs of human labour, water for irrigation, total fertilizer and machinery contributed significantly to the yield. The impact of human labour energy (0.17) was found the highest among the other inputs in kiwifruit production. The results also showed that direct, indirect and renewable and non-renewable, energy forms had a positive impact on output level. Cost analysis showed that total cost of kiwifruit production was obtained as 6063.81 \$ ha^{-1}. The productivity (4.05 kg $\$^{-1}$) was obtained by dividing kiwifruit yield by total production cost.

1. Introduction

Kiwifruit *(Actinidia deliciosa)* is a commonly eaten fruit in certain countries. Kiwifruit originates from an indigenous plant of Southern China (*Actinidia Chinensis*) which was first developed commercially in New Zealand at the beginning of the 20th century [1]. Iran is the 8th largest kiwifruit production after Italy, New Zealand, Chile, France, Greece, Japan and USA, respectively [2]. The production of kiwifruit is about 20,000 tons/year in Iran and the cultivation land area is about 1,500 hectares in 2007 [2]. Mazandaran province is one of the important producers of kiwifruit, today; about 71.46% of kiwifruit production in Iran is provided from this province [3].

Energy use is one of the key indicators for developing more sustainable agricultural practices. Wider use of renewable energy sources, increase in energy supply and efficiency of use can make a valuable contribution to meet sustainable energy development targets [4]. In agriculture, a wide range of modern and traditional energy forms are used directly on the farm, e.g. as tractor or machinery fuel, and in water pumping, irrigation and crop drying, and indirectly for fertilizers and pesticides. Other energy inputs are required for post harvest processing in food production, packaging, storage, transportation and cooking [5].

The size of the population engaged in agriculture, the amount of arable land and the level of mechanization are the important factors that energy utilization in the agricultural sector depends to them [6]. Energy productivity is an important index for more efficient use of energy although higher energy productivity does not mean in general, more economic feasibility. However, the energy analysis shows the methods to minimize the energy inputs and therefore to increase the energy productivity [7].

Kizilaslan [8] studied energy use for cherries production in Turkey. For this purpose he calculated input–output energy, energy productivity and energy forms of direct, indirect, renewable and non-renewable. Strapatsa et al. [9] surveyed energy inputs for apple production to determine the most energy consuming operations. They carried out the study during 1999–2000 period at 26 apple orchards in Zagora Pelion (Central Greece). In a research Chile, energy consumption in the production of fruits was examined to improve the efficiency of its use. In this study the data were collected from 187 producers in 1992–1995 periods. Fruits investigated were grapes, raspberry, orange, lemon, plum, pear and apple [10]. Singh et al. [11] investigated energy consumption in wheat production for five agro-climatic zones of Punjab. In this research, sensitivity of a particular energy input level on productivity was evaluated. Although many experimental works are conducted on energy use in

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Nomenclature

n	required sample size
N	number of holdings in target population
N_h	number of the population in the h stratification
S_h^2	variance of h stratification
d	precision $(\bar{x} - \bar{X})$
z	reliability coefficient (1.96 in the case of 95% reliability)
D^2	d^2/z^2
Y_i	yield level of the i'th farmer
X_1	labour energy
X_2	machinery energy
X_3	diesel fuel energy
X_4	total fertilizer energy
X_5	chemicals energy
X_6	water for irrigation energy
e_i	error term
α_i	coefficients of the variables
β_i	coefficients of the variables
γ_i	coefficients of the variables
DE	direct energy
IDE	indirect energy
RE	renewable energy
NRE	non-renewable energy

agricultural crops [12–20], there are not any studies on the energy analysis of kiwifruit production in Iran.

The main aim of this study is to analyze the energy use and evaluate the relationship between inputs and output for kiwifruit production and compare input energy use with input costs based on kiwifruit farms in Mazandaran, Iran.

2. Material and methods

In this study, kiwifruit growers were surveyed in 14 villages from Mazandaran province, Iran. The Mazandaran province is located in the north of Iran, within 31° 47' and 38° 05' north latitude and 50° 34' and 56° 14' east longitude. Data were collected from 86 kiwifruit orchards by using a face-to-face questionnaire performed. The size of each sample was determined using Eq. (1) derived from Neyman technique [21].

$$n = \frac{(\sum N_h S_h)}{N^2 D^2 + \sum N_h S_h^2} \tag{1}$$

where n is the required sample size; N is the number of holdings in target population; N_h is the number of the population in the h stratification; S_h is the standard deviation in the h stratification, S_h^2 is the variance of h stratification; d is the precision where $(\bar{x} - \bar{X})$; z is the reliability coefficient (1.96 which represents the 95% reliability); $D^2 = d^2/z^2$.

For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used. Thus, the number of 86 was considered as sampling size, and these 86 farms were selected randomly. The input energy was divided into direct and indirect and renewable and non-renewable forms [22]. Direct energy constituted human labour and diesel fuel, whereas, indirect energy encompassed farmyard manure, chemical fertilizer, chemicals, machinery and water for irrigation. Renewable energy consists of human labour, farmyard manure and water for irrigation and non-renewable energy includes machinery, diesel fuel, chemical fertilizers and chemicals. Human labour, machinery, diesel fuel, chemical fertilizers, farmyard manure, chemicals, water for irrigation, and output yield values of kiwifruit have been used to estimate the energy input-output ratio. Energy equivalents shown in Table 1 were used for estimation in this study.

Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity, specific energy, net energy and energy intensiveness were calculated [14,19] as follows:

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

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

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

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

$$\text{Energy intensiveness} = \frac{\text{Energy input}\left(\text{MJ ha}^{-1}\right)}{\text{Cost of cultivation}\left(\$\text{ ha}^{-1}\right)} \tag{6}$$

In order to analyze the relationship between energy inputs and energy output, different functions were investigated and with respect to the experiments related to selecting optimized functions. The Cobb–Douglas function was selected as the function suitable pattern. Several authors used Cobb–Douglas function to evaluate the relationship between energy inputs and production [11,23,28]. Cobb–Douglas function is expressed as follows:

$$Y = f(x)\exp(u) \tag{7}$$

which can be further written as:

$$\ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad i = 1, 2, \ldots, n \tag{8}$$

where Y_i denotes the yield of the i'th farmer, X_{ij} is the vector of inputs used in the production process, a is a constant, α_j represents coefficients of inputs which are estimated from the model and e_i is the error term. Eq. (8) can be expressed in the following form;

$$\ln Y_i = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + e_i \tag{9}$$

where human labour energy (X_1), machinery energy (X_2), diesel fuel energy (X_3), total fertilizer energy (X_4), chemicals energy (X_5), water for irrigation energy (X_6).

With respect to this pattern, in this study, first, the impact of the energy of each input on the kiwifruit yield was studied and second, the impact of direct and indirect energies, and renewable and non-renewable energies on the production were studied. For this purpose, Cobb–Douglas function was determined in the following forms (10), (11), respectively;

$$\ln Y_i = \beta_0 + \beta_1 \ln \text{DE} + \beta_2 \ln \text{IDE} + e_i \tag{10}$$