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# Energy use pattern and sensitivity analysis of energy inputs and input costs for pear production in Iran

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ABSTRACT

The purposes of this study were to determine energy use pattern and investigate the relationships between energy inputs and yield, cost inputs and income for pear production in the Tehran province of Iran. In this study, data were collected by administering a questionnaire in face-to-face interviews in the production year of 2009/2010. This article presents a comprehensive picture of the current status of energy consumption and some energy indices like energy ratio, energy productivity, specific energy, net energy and energy intensiveness. Results showed that the total energy input of 172,608.43 MJ ha$^{-1}$ was required for pear production. Among input energy sources, electricity energy with share of 78% of total input energy had the highest share. The energy use efficiency and energy productivity were found as 0.51 and 0.27 kg MJ$^{-1}$, respectively. To investigate the relationships between energy inputs and yield, cost inputs and income, Cobb–Douglas production function was selected as the best function. Sensitivity analysis of energy and cost inputs was carried out using the marginal physical productivity (MPP) technique. Economic analysis of pear production was carried out and total cost of pear production was obtained as 11,936.97 $ h$^{-1}$. Also the benefit to cost ratio was calculated as 3.11.



## 1. Introduction

Pears (*Pyrus Communis L.*) are qualified as a good source of vitamin C and copper in our food ranking system. Both of these nutrients can be thought of as antioxidant nutrients that help protect cells in the body from oxygen-related damage due to free radicals [1]. In the world, pears are produced about 21.9 million tons from 1.7 million ha in 2009 [2]. China had the first place in producing pears while Netherlands, Argentina, Belgium and Italy were important pears exporting countries in 2008. Iran with producing 115,812 tons of pears had the 20th place in pears production in the world in 2008 [2].

The agriculture sector, like other sectors, has become increasingly dependent on energy resources such as electricity, fuels, natural gas and coke. This increase in energy use and its associated increase in capital intensive technology can be partially attributed to low-energy prices in relation to the resource for which it was being substituted [3]. Modern crop production is characterized by the high input of fossil energy, which is consumed as “direct energy” (fuel and electricity used on the farm) and as “indirect energy” (energy spent beyond the farm for the manufacture of fertilizers, plant protection agents, machines, etc.) [4]. The increased use of agricultural inputs in modern farming has resulted in an increase in the energy inputs for fertilizer and crop protection chemicals, higher yields have increased the energy output per unit area and per unit of input [5]. A significant objective in agricultural production is to decrease costs and increase yield. In this respect, the energy budget is important. Energy budget is the numerical comparison of the relationship between input and output of a system or agricultural business in terms of energy units [6]. In order to evaluate the sustainability of agriculture per se, the energetic efficiency must be considered and the major sources of energy wastes must be identified and assessed [7]. Several studies have been conducted about energy analysis of agricultural crops production. Rajabi Hamedani et al. [8] analyzed energy use pattern of grape production in Iran. Mohammadi et al. [9] investigated energy inputs–yield relationship and cost analysis of kiwifruit production in Iran. They used Cobb–Douglas production function to estimate a relationship between energy inputs and yield. Esengun et al. [10] analyzed energy consumption of dry apricot production in Turkey. Hartirli et al. [11] studied energy inputs and crop yield relationship in greenhouse tomato production. Strapatsa et al. [12] investigated energy flow for integrated apple production in Greece. Ozkan et al. [13] examined energy use patterns and the relationship between energy inputs and yield for double crop (fall and summer) glasshouse tomato production in Turkey.

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In literature review there are many studies about agricultural products but there is no study about energy and cost analysis of pear production; so the objectives of this study were to determine the energy use pattern of pear production to investigate the efficiency of energy and to make a cost analysis of pear production. This study also generates the relationships between energy inputs and yield, cost inputs and income and analyzes sensitivity of inputs for pear production in Tehran province, Iran.

## 2. Materials and methods

This study was carried out in the orchards located in Tehran province, Iran. Tehran province had the second place in producing pear in Iran in 2009 [14]. Tehran is located within 35° 34′ and 35° 50′ north latitude and 51° 02′ and 51° 36′ east longitude. Data were collected by using a face-to-face questionnaire performed in the production year 2009/2010. Average orchard size was 0.7 ha in the area studied while the size of orchards varied between 0.2 ha and 2 ha. From the villages in the area studied, orchards were selected by using stratified sample randomly. The sample size was calculated using Cochran method [15]:

$$n = \frac{N(S \times t)^2}{(N-1)d^2 + (S \times t)^2} \quad (1)$$

where $n$ is the required sample size; $N$ is the number of holdings in target population; $t$ is the reliability coefficient (1.96 which represents the 95% reliability); $S^2$ is the variance of studied qualification in population; $d$ is the precision $(\bar{x} - \overline{X})$. The permissible error in the sample size was defined to be 5% for 95% confidence. Based on this method of sampling, 100 farms were investigated.

Energy requirements in agriculture are divided into four groups: direct, indirect, renewable and non-renewable. In this study, direct energy included electricity, human labor, gasoline fuel and water for irrigation and indirect energy included chemical fertilizers, farmyard manure and chemical biocides. Also, non-renewable energy included gasoline fuel, electricity, chemical biocides and chemical fertilizers, while human labor, farmyard manure and water for irrigation were considered as renewable energy [16]. The only output energy source was pear fruit. In the surveyed area all the horticultural operations were carried out by human labor except chemical spraying. Since these sprayers were about 25–30 kg in weight and 25–30 years of life, calculating machinery energy related to their manufacturing was found to be insignificant and was not considered in the analysis. Also, these sprayers consumed gasoline fuel. The energy values were calculated by transforming data using energy equivalents shown in Table 1.

The energy input–output ratio (energy use efficiency), energy productivity, specific energy, net energy and energy intensiveness were calculated using the following equations [9]:

Energy ratio (Energy use efficiency) = Energy output (MJ ha$^{-1}$)/Energy input (MJ ha$^{-1}$) (2)

Energy productivity = Pear yield (kg ha$^{-1}$)/Energy input (MJ ha$^{-1}$) (3)

Specific energy = Energy input (MJ ha$^{-1}$)/Pear yield (kg ha$^{-1}$) (4)

Net energy = Energy output (MJ ha$^{-1}$) − Energy Input (MJ ha$^{-1}$) (5)

Energy intensiveness = Energy Input (MJ ha$^{-1}$)/Cost of cultivation ($ ha$^{-1}$) (6)

**Table 1**
Energy equivalents of inputs and output in pear production.

| Particulars | Unit | Equivalent (MJ unit$^{-1}$) | Ref. |
|---|---|---|---|
| *A. Inputs* | | | |
| 1. Human labor | h | 1.96 | [17] |
| 2. Gasoline fuel | L | 46.3 | [18] |
| 3. Chemical fertilizers | kg | | |
| (a) Nitrogen (N) | | 66.14 | [9,19,20] |
| (b) Phosphate ($P_2O_5$) | | 12.44 | [9,19,20] |
| (c) Potassium ($K_2O$) | | 11.15 | [9,19,20] |
| 4. Farmyard manure | kg | 0.3 | [21] |
| 5. Chemical biocides | kg | 120 | [9,21] |
| 6. Electricity | kWh | 3.6 | [20] |
| 7. Water for irrigation | $m^3$ | 1.02 | [22] |
| *B. Output* | | | |
| 1. Pear | kg | 1.9 | [23,24] |

The energy consumed by electromotor of water pump for pumping water from water wells in the form of electricity, was calculated by using Eq. (7) [18]:

$$\mathrm{DE} = \frac{\gamma g H Q}{\varepsilon_p \varepsilon_q} \quad (7)$$

where DE denotes direct energy (J ha$^{-1}$), g is acceleration due to gravity (m s$^{-2}$), $H$ is total dynamic head (m), $Q$ indicates volume of required water for one cultivating season (m$^3$ ha$^{-1}$), $\gamma$ is density of water (kg m$^{-3}$), $\varepsilon_p$ is pump efficiency (70–90%), $\varepsilon_q$ is total power conversion efficiency (18–20%) [18].

In the surveyed area, the input costs for pear production were chemical biocides, farmyard manure, chemical fertilizers, human labor, transportation and fuel, packing, water and land renting expenses. Also, the electricity expense was included in water expense.

Production function represents technically efficient transform of physical resources ($X_i$) into product or outputs ($Y_j$). The Cobb–Douglas functional form of production functions is widely used to represent the relationship of an output to inputs. So in this study the Cobb–Douglas function was used in order to specify relationships between input energies and yield, input cost and income. The Cobb–Douglass production function is expressed as:

$$Y = f(x)\exp(u) \quad (8)$$

This function has been used widely by several authors to investigate the relationship between energy inputs and yield [9,11,25–27].

This function can be written in linear form as:

$$\ln Y_i = \alpha_0 + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i \quad i = 1, 2, \ldots, 100 \quad (9)$$

where $Y_i$ denotes the yield level of the $i$th farmer, $X_{ij}$ is the vector inputs used in the production process, $\alpha_0$ is the constant term, $\alpha_j$ represents coefficients of inputs which are estimated from the model and $e_i$ is the error term. With the assumption that the yield is a function of energy inputs, Eq. (9) can be expressed as:

$$\ln Y_i = \alpha_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \ldots + \alpha_7 \ln X_7 + e_i \quad (10)$$

where $X_1$, $X_2$, $X_3$, $X_4$, $X_5$, $X_6$ and $X_7$ are human labor, gasoline fuel, chemical fertilizers, farmyard manure, chemical biocides, electrical and water for irrigation energies respectively.

Also the impact of input costs on income was investigated using Cobb–Douglas function represented by Eq. (11):