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Energy consumption flow and econometric models of two plum cultivars productions in Tehran province of Iran

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A B S T R A C T

In this study the amount of energy consumption and its relation with yield in producing two cultivars of plum, Ghatreh Tala and Shablon cultivars, in Tehran province of Iran were studied. For each one of plum cultivars, data were obtained from 100 farmers in the form of personal interview using structured questionnaire method in Tehran province of Iran. Total input energy was found to be 192,652.55 and 168,783.94 MJ ha^{-1} for Ghatreh Tala and Shablon cultivars production. In Ghatreh Tala and Shablon cultivars production among input energy sources, electricity energy had the highest share with shares of 79.07% and 80.28% of total input energy respectively. Cobb–Douglass production function was used to determine a relation between input energies and yield in both productions. Results indicated that by using Cobb–Douglass production function to determine mathematical relationship between energy input and yield, human labor energy had the highest impact on yield for both productions. Sensitivity analysis indicated that among the energy inputs human labor energy had the highest MPP value for both plum cultivars productions. The benefit-cost ratios from Ghatreh Tala and Shablon productions were calculated to be 4.18 and 2.46, respectively.

1. Introduction

Plums (*Prunus domestica* L.) are the most taxonomically diverse of stone fruits and are adapted to a board range of climatic and edaphic factors [1]. Plums constitute the most numerous and diverse group of fruit tree species. The wide variety of plums, the distribution of the fruit through a wide area, and its adaptability to varying conditions make it, not only of great importance at present, but also for future development [2]. Plums also have the potential to contribute greatly to human nutrition because plums are sources of essential nutrients, vitamins and minerals [3].

In the world, plums and sloes are produced about 10.7 million tons from 2.5 million ha in 2009. China has the first place in producing plums and sloes while Spain, China, USA and Netherlands are important plums and sloes exporting countries. Iran produced 190,621 tons of plums and sloes in 2008 [4].

Energy is a fundamental component in the process of economic development, as it provides imperative services that maintain economic activity and the quality of human life. Thus, shortages of energy are a serious constraint on the development of low income countries [5]. Shortages are caused or aggravated by widespread technical inefficiencies, capital constraints and a pattern of subsidies that undercut incentives for conservation [6]. There is a close relationship between agriculture and energy. While agriculture uses energy, it also supplies it in the form of bio-energy. At the present time, the productivity and profitability of agriculture depend upon energy consumption [7]. Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices, or both [8]. 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 [9]. In calculating the energy balance for crop production, various methods may be implemented, depending on the goal of the study; there is no standard method for computing the energy balance [10]. Therefore, research efforts have emphasized energy and economic analysis of various agricultural productions for planning resources in the ecosystem [11]. Several researches have been done in determining energy indices for various agricultural products and estimating a relationship between energy input and yield. Esengun et al. [8] studied about Input–output energy analysis of dry apricot production in Turkey. Strapatsa et al. [12] studied energy inputs for

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integrated apple production, to investigate the most energy consuming operations. Mohammadi et al. [13] studied about analyzing energy inputs for kiwifruit production and determined a mathematical relationship between energy input and yield. Kizilaslan [14] investigated the energy use for cherries production in Turkey. For this purpose, the share of each energy input, output–input energy ratio, energy productivity and shares of energy forms including direct, indirect, renewable and non-renewable were calculated. Also many experimental works have been conducted on energy use in agriculture such as greenhouse vegetable in Turkey [15], citrus in Antalya province of Turkey [16], grape in Hamadan province of Iran [17] and onion in Pennsylvania state, USA [18].

Tehran region is one of the six biggest producer provinces of horticultural products in Iran.

The main horticultural products of Tehran region are apple, cherries, apricot, plums, peach and grape, while apple and plum cultivars are the main crops produced in Tehran region. Tehran province had the first place in producing plums in Iran in 2009 [19]. The numbers of beneficiaries in horticulture section were about 57,654 in Tehran province. Ghatreh Tala and Shablon cultivars are the most common cultivars of plum cultivated in Tehran region. The main problems faced by plum cultivars producers are lack of a national program relating to horticulture management, pests and plant diseases control and irrigation management. Also the main economic problem faced by these producers is instability in market prices.

So far there was no study about energy analysis of plums in literature review, so the aims of this study were to analyze energy input–output and estimation of relationships between energy input and yield of two cultivars of plum in Tehran province of Iran. Also in this study the economy of two plum cultivars produced in the area studied were analyzed.

2. Materials and methods

This study was conducted in Tehran province and the selection of Tehran region as the case study was basically due to its major contribution from plum production in Iran. The Tehran province is located within 35° 34′ and 35° 50′ north latitude and 51° 02′ and 51° 36′ east longitude. In the studied area for Ghatreh Tala cultivar, average orchard size was 0.9 ha with a range from 0.3 up to 4 ha and for Shablon cultivar, average orchard size was 0.5 ha with a range from 0.2 up to 2 ha. Villages in which plum is widely grown were determined in the surveyed area. So, fifteen villages were chosen to represent the whole study area. Then, farmers who are producing plum were recorded, the sizes of each orchard and total land area were settled, thus the statistical population was specified. The orchards in the surveyed area were clustered into three with respect to orchards area. This clustering enabled homogenisation of enterprises through grouping of enterprises by size [20]. As it is obvious collection of data from whole population is not affordable and practical, therefore, stratified random sampling method was employed in order to collect data. The sample size for each cluster was determined using the Cochran method [21].

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

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 ($\bar{x}-\bar{X}$). 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 for each one of the plum cultivars.

In this region the input energy sources for plum production were human labor, gasoline fuel, fertilizers (nitrogen, phosphorus, potassium and farmyard manure), chemical biocides, electricity and water for irrigation; while the only output energy source was plum fruit. Also in this region 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. Based on the energy equivalents of the inputs and output (Table 1), the energy indices such as energy ratio (energy use efficiency), energy productivity and the specific energy were calculated [13].

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

Energy productivity = Plum output (kg ha^{-1})/Energy input (MJ ha^{-1}).

Specific energy = Energy input (MJ ha^{-1})/Plum output (kg ha^{-1}).

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

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

For calculating required energy for pumping water from water wells in the form of electricity energy, Eq. (2) was used [22]:

$$\mathrm{DE} = \frac{\gamma g H Q}{\varepsilon_p \varepsilon_q} \quad (2)$$

where DE denotes direct energy (J/ha), g is acceleration due to gravity (m s^{-2}), H is total dynamic head (m), Q is volume of required water for one cultivating season (m^3 ha^{-1}), γ is density of water (kg m^{-3}), ε_p is pump efficiency (70–90%) and ε_q is total power conversion efficiency (18–20%) [24].

In order to determine a mathematical relationship between energy inputs and yield Cobb–Douglas production function was used in this study. Production function is a function that specifies the output of a farm, an industry, or an entire economy for all combinations of inputs. The Cobb–Douglas production function yielded the best estimates in terms of statistical significance and expected signs of parameters [21]. The Cobb–Douglass production function is expressed as:

$$Y = f(x)\exp(u) \quad (3)$$

This function is used widely by several researchers to examine the relationship between energy inputs and yield [17,20,25,26].

This function can be written in linear form as:

Model I:

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

Particulars	Unit energy	Equivalent (MJ unit^{-1})	Ref.
A. Inputs			
1. Human labor	h	1.96	[13]
2. Gasoline fuel	L	46.3	[21]
3. Fertilizers	kg		
(a) Nitrogen (N)		66.14	[13,17]
(b) Phosphorus (P_2O_5)		12.44	[13,17]
(c) Potassium (K_2O)		11.15	[13,17]
(d) Farmyard manure	kg	0.3	[13]
4. Chemical biocides	kg	120	[13]
5. Electricity	kWh	3.6	[27]
6. Water for irrigation	m^3	1.02	[27]
B. Outputs			
1. Ghatreh Tala	kg	1.9	[23]
2. Shablon	kg	1.9	[23]