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Investigation of energy inputs for peach production using sensitivity analysis in Iran

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A B S T R A C T

The purpose of this research was to investigate the energy balance between the energy inputs and yield in peach production in Golestan province of Iran as a case study. The results showed that total energy consumption in peach production was 37536.96 MJ ha^{-1} where the diesel fuel with about (26.32%) was the major energy consumer. The direct energy shared about (50.98%) whereas the indirect energy did (49.02%). Energy use efficiency, energy productivity, specific energy and net energy were 0.55, 0.29 kg MJ^{-1}, 3.41 MJ kg^{-1} and −16642.03 MJ ha^{-1}, respectively. Econometric assessment results revealed that the energy inputs of human labor, machinery, diesel fuel, chemical fertilizers and farm yard manure had significant influence on the yield. The impact of human labor energy (1.36) was found as the highest among the other input parameters. Sensitivity analysis indicated that the MPP value of energy inputs was between −2.8 and 11.31. Also the MPP value of human labor was the highest, followed by diesel fuel and farm yard manure energy inputs, respectively.

1. Introduction

Peach (*Prunus persica*) is a member of the *Rosaceae* family, the peach is thought to be originated in China and spread to the rest of the world by means of seeds. The botanical name of peach (*Prunus persica*) refers to the putative country of origin, Persia (Iran). Its species well adapted to temperate and subtropical regions, between latitudes of 30° and 45° north and south [1,2]. Iran is one of the main cultivation regions and it is the 6th largest producer of peach after China, Italy, United States of America, Spain and Greece, respectively. The production of peach and the other nectarines was about 574958 tons/year in Iran [3] and the cultivation land area was about 56562 ha in 2008 from which 6% was the share of Golestan Province [4].

Agriculture is considered as a supplier and consumer of energy. It uses large quantities of locally available non-commercial inputs, such as seed, manure and animate energy, and commercial inputs directly and indirectly in the form of fuel, electricity, fertilizer, plant protection, chemicals, irrigation water and machinery. They all can be converted and stated in the form of energy units. Efficient use of energies helps to achieve increased production and productivity and contributes to the economy, profitability and competitiveness of agriculture sustainability in rural living [5]. Energy use in agriculture has developed in response to growing populations, limited supply of arable land and desire for an increasing demand for standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor intensive practices or both [6]. Energy requirements in agriculture are divided into four groups: direct and indirect, non-renewable and renewable energies. Direct energy (DE) includes energy embodied in human labor, diesel fuel, water for irrigation and electricity while indirect energy (IE) refers to chemical fertilizers, farm yard manure, chemicals and machinery used in the agricultural production. Non-renewable energy (NRE) includes chemicals, machinery, diesel fuel, electricity and chemical fertilizers, and renewable energy (RE) consisted of human labor, farm yard manure and water for irrigation [7]. Energy input–output relation analysis is usually used to appraise the efficiency and environmental effects of the production systems. This analysis will determine how efficient the energy is used. Several studies have been conducted on energy analysis in agriculture such as apple, canola, soybean, barley, alfalfa, strawberry, potato, and kiwifruit in Iran [8–15], apricot, canola, field crops and vegetables, cotton, cherry, sweet cherry, tomato, pomegranate, sugar beet, citrus in turkey [16–25], wheat, maize and sorghum in United States [26,27], wheat, maize, sugar beet, sunflower, grape, olive, almond, barley, oat, rye, orange, lemon, apple, pear, peach, apricot and plum in Italy [28], apple, sunflower and cotton in Greece [29–31], wheat and cotton in Punjab [32,33], rice in Malaysia [34], wheat in New Zealand [35], cereal, potato, sugar beet in Denmark [36], soybean in India [37]. But there is not an exhaustive publication analyzing energy input–output and sensitivity analysis in peach production. Therefore the main objectives of this study were to establish the energy use efficiency per hectare, to analyze the sensitivity of energy inputs and also to determine relationship between energy

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Nomenclature

n	required sample size	X_8	electricity energy
N	number of holdings in target population	e_i	error term
s	standard deviation	α_i	coefficients of the exogenous variables
d	acceptable error (permissible error was chosen as 5%)	β_i	coefficients of the exogenous variables
t	confidence limit (1.96 in the case of 95% reliability)	γ_i	coefficients of the exogenous variables
Y_i	yield level of the ith farmer	DE	direct energy
X_1	labor energy	IDE	indirect energy
X_2	machinery energy	RE	renewable energy
X_3	diesel fuel energy	NRE	non-renewable energy
X_4	chemicals energy	$MPPx_j$	marginal physical productivity of jth input
X_5	chemical fertilizer energy	α_j	regression coefficient of jth input
X_6	farm yard manure energy	GM(Y)	geometric mean of yield
X_7	water for irrigation energy	GM(X_j)	geometric mean of jth input energy

inputs and yield using mathematical models on the peach orchards in Golestan province, Iran.

2. Materials and method

This research was conducted in Golestan province as one of the main agricultural production areas of Iran. The Golestan province is located in the north-east of Iran, within 36° 50′ and 36° 50.19′ north latitude and 54° 25′ and 54° 25.95′ east longitude. The total area of the Golestan province is 2019423 ha which it has (1.3%) of total area of the country and the farming area is 657557 ha, with a share of (32.56%). Data were collected from the growers of 75 peach orchards using a face-to-face questionnaire which carried out in July and August 2010. The sample size of orchards in the research area was calculated using the Cochran method that is one of the stratified random sampling techniques [38]:

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

where n, s, t and N are the required sample size, the standard deviation, the reliability coefficient (1.96 that indicates the 95% reliability) and the number of holding in target population, respectively and d is the acceptable error (permissible error 5%) which calculated with this equation;

$$d = \frac{t \times s}{\sqrt{n}} \tag{2}$$

Hence, according to forenamed equations the sample size in this study was computed 75. The energy inputs for the peach production in this area included chemicals, diesel fuel, electricity, chemical fertilizers, farm yard manure, water for irrigation, human labor and machinery; while energy output was the production value of peach fruit. The energy equivalent of inputs and output, are illustrated in Table 1, were used to appraise the energy value. The input and output were calculated per hectare and then, these input and output data were multiplied by the coefficient of energy equivalent. The energy equivalences of inputs are given in Mega Joule (MJ). The total input equivalent can be computed by the summation of energy components for all inputs in Mega Joule (MJ). According to the energy equivalents as mentioned in Table 1, the energy use efficiency (energy input output ratio), energy productivity, the specific energy and the net energy gain, were calculated as [14,41]:

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \tag{3}$$

$$\text{Energy productivity} = \frac{\text{Production (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \tag{4}$$

$$\text{Specific energy} = \frac{\text{Energy Input (MJ ha}^{-1})}{\text{Production (kg ha}^{-1})} \tag{5}$$

$$\text{Net energy} = \text{Energy Output (MJ ha}^{-1}) - \text{Energy Input (MJ ha}^{-1}) \tag{6}$$

Cobb–Douglas functions are frequently used in economics to show the relationship between input factors and the level of production. The Cobb Douglas production function is expressed as follow:

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

This function has been applied by a number of authors to seek the relationship between yield and energy inputs [8,11,32]. Eq. (7) can be linearized and be further re-written as:

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

Eq. (8) can be expressed in the following form:

$$\ln Y_i = a_0 + \alpha_1 \ln X_1 + \alpha_2 \ln X_2 + \alpha_3 \ln X_3 + \alpha_4 \ln X_4 + \alpha_5 \ln X_5 + \alpha_6 \ln X_6 + \alpha_7 \ln X_7 + \alpha_8 \ln X_8 + e_i \tag{9}$$

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

Inputs	Unit	Energy equivalent	References
A. Inputs			
1. Human labor	h	1.96	42
2. Machinery	h	62.7	45
3. Diesel fuel	l	56.31	44
4. Chemicals	kg		
a. Herbicides		238	8
b. Insecticides		101.2	8
c. Fungicides		216	8
d. Mineral oil		43.2	8
5. Chemical fertilizer	kg		
a. Nitrogen		66.14	22
b. Phosphate (P2O5)		12.44	22
c. Potassium (K2O)		11.15	22
d. Sulphur (S)		1.12	42
6. Farmyard manure	kg	0.3	42
7. Water for irrigation	m3	1.02	11
8. Electricity	kwh	11.93	44
B. Output			
1. Peach fruit	kg	1.9	45